IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF ARKANSAS
TEXARKANA DIVISION

6,074,069

INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE,	§	
Plaintiff,	§	Civil Action No. 09-4110
v.	§	JURY DEMANDED
SAMSUNG ELECTRONICS AMERICA, INC., SAMSUNG TELECOMMUNICATIONS AMERICA, L.L.C., AND SAMSUNG ELECTRONICS CO., LTD.,	§	
Defendants.	§	

PLAINTIFF'S FIRST AMENDED COMPLAINT FOR PATENT INFRINGEMENT AND JURY DEMAND

Plaintiff Industrial Technology Research Institute ("ITRI") brings this action for patent infringement against Samsung Electronics America, Inc., Samsung Telecommunications America, L.L.C., and Samsung Electronics Co., Ltd. (collectively, "Samsung") as follows:

I. THE PARTIES

1. Plaintiff Industrial Technology Research Institute ("ITRI") is the Republic of China, Taiwan's scientific research institution having a principal address of 195, Sec. 4, Chung Hsing Rd., Chutung, Hsinchu, Taiwan 31040, R.O.C.

2. Upon information and belief, Samsung Electronics America, Inc. is, and at all relevant time mentioned herein was, a corporation organized under the laws of New

VII. INFRINGEMENT OF U.S. PATENT NO. 6,883,932

47. On April 26, 2005, the USPTO issued U.S. Patent No. 6,883,932, entitled "Apparatus for Improving Uniformity Used in a Backlight Module" (hereinafter "the '932 patent"). A true and correct copy of the '932 patent is attached hereto as Exhibit E.

48. ITRI is the owner of all right, title, and interest in and to the '932 patent by assignment, with full right to bring suit to enforce the patent, including the right to recover for past infringement damages and the right to recover future royalties, damages, and income.

49. The '932 patent is valid and enforceable.

50. All requirements under 35 U.S.C. § 287 have been satisfied with respect to the '357 patent.

51. Samsung has been and is infringing the '932 patent by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '932 patent, including but not limited to Samsung products bearing flat panel displays such as the Samsung display LN40A630M1F .

52. Samsung has been and is continuing to induce infringement of the '932 patent under 35 U.S.C. § 271(b) and contributes to the infringement of the '932 patent under 35 U.S.C. § 271(c), in conjunction with such acts of making, using, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '932 patent. The infringing instrumentalities have no substantial non-infringing uses.

ORGANIC LIGHT EMITTING DIODE WITH BRIGHTNESS ENHANCER

BACKGROUND

The invention relates to an organic light emitting diodes (OLED) and in particular to an OLED with a brightness enhancer.

OLED qualities such as light weight, slim profile, low power consumption, wide viewing angle and fast response time make it is a popular display choice. When luminescent efficiency of the OLED reaches 100 Lm/W, it can replace conventional light sources. Thus improving OLED efficiency is an important issue.

Recently, lifetime and brightness of OLEDs have improved, but not substantially. Organic materials and glass substrate have a higher refraction than air, such that light easily reflects or emits from device sides. About 80% light is trapped in the device, making the quantum efficiency of OLED less than 20%.

An improved OLED device **10** is shown in FIG. **1**, comprising polarizing film **11**/substrate **13**/anode electrode **14**/organic light emitting layer **15**/and cathode electrode **16** encapsulant (not shown). The metal electrode provides good the reflection performance, however, double image is induced by exterior light entering the OLED device and reflecting. A polarizing film **11** with a ¼ wavelength delayer layer eliminates this problem. However, polarizing film **11** decreases brightness by more than ½, because it not only blocks exterior light but also light emitting from the device.

SUMMARY

Accordingly, embodiments of the invention provide a organic light emitting diode (OLED) with a brightness enhancer.

In an embodiment of the invention, an organic light emitting diode (OLED) with a brightness enhancer comprises a substrate having a first surface and a second surface opposite thereto. An anode electrode is disposed on the first surface of the substrate. An organic light emitting layer is disposed on the anode electrode. A cathode electrode is disposed on the organic light emitting layer. A brightness enhancer is disposed on the second surface of the substrate.

In another embodiment, an organic light emitting diode (OLED) with a brightness enhancer comprises a substrate. An anode electrode is disposed on the substrate. An organic light emitting layer is disposed on the anode electrode. A cathode electrode is disposed on the organic light emitting layer. A brightness enhancer is disposed on the cathode electrode.

DESCRIPTION OF THE DRAWINGS

The embodiments can be more fully understood by reading the subsequent detailed description and examples with references made to the accompanying drawings, wherein:

FIG. **1** is a cross section of a conventional OLED structure.

FIG. **2** is a cross section of an OLED with a brightness enhancer according to the first embodiment of the invention.

FIG. **3** is a cross section of an OLED with a brightness enhancer according to the second embodiment of the invention.

FIG. **4** is a cross section of an OLED with a brightness enhancer according to the third embodiment of the invention.

DETAILED DESCRIPTION

The invention provides an OLED to enhance luminescent efficiency. The OLED of the invention is a conventional OLED with a cholesterol liquid crystal thin film layer as a brightness enhancer, drawing trapped light out of the device to enhance luminescent efficiency. FIGS. **2**–**4** are cross sections of OLEDs with brightness enhancers.

First Embodiment

FIG. **2** is a cross section of an OLED with a brightness enhancer according to the first embodiment of the invention. The OLED comprises a substrate **13**. An anode electrode **14** is formed on the substrate **13**. The anode electrode **14** comprises a transparent electrode, a metal electrode or a complex electrode. An organic light emitting layer **15** is formed on the anode electrode **14**. The organic light emitting layer **15** comprises monolayer or multilayer small molecular or polymer organic light emitting materials. The organic light emitting layer **15** is formed by thermal evaporating small molecular organic light emitting material under vacuum, or by spin-coating, ink-jetting or screen printing the polymer organic light emitting material. The organic light emitting layer **15** further comprises at least one electron injection layer and/or an electron transfer layer thereon, and at least a hole injection layer and a hole transfer layer beneath the organic light emitting layer **15**.

A cathode electrode **16** is formed on the organic light emitting layer **15**. The cathode electrode **16** comprises a transparent electrode, a metal electrode or a complex electrode. The anode electrode **14** and cathode electrode **16** are formed by sputtering, electron beam evaporation, thermal evaporation, chemical vapor deposition or spray pyrolysis. A brightness enhancer **12** is posted on the other surface of the substrate **13**, and a polarizing film. **11** is posted on the brightness enhancer **12**. The OLED has a structure comprising polarizing film **11**/brightness enhancer **12**/substrate **13**/anode electrode **14**/organic light emitting layer **15**/cathode electrode **16**. The invention is not limited to the above fabrication technologies, and other suitable methods can be used.

Since light **18** is emitted through the substrate **13** of the device **10**, substrate **13** transparent, such as glass or plastic substrate. The polarizing film **11** polarizes light **18** due to dichromatic or double refraction of specific substance, or reflection or refraction at an interface between two substances. The brightness enhancer **12** comprises a cholesterol liquid crystal thin film layer or multilayer thin film layer, such as 3M. DBEF series device. Preferably, the anode electrode **14** comprises transparent indium tin oxide (ITO) or indium zinc oxide (IZO). The organic light emitting layer **15** preferably comprises OLED or polymer light emitting diode (PLED). The cathode electrode **16** preferably comprises Al, Mg, Ag, Ca or alloys thereof.

Second Embodiment

FIG. **3** is a cross section of an OLED with a brightness enhancer according to the second embodiment of the invention. The OLED **30** has a structure of substrate **13**/node electrode **14**/organic light emitting layer **15**/cathode electrode **16**/brightness enhancer **12**/transparent encapsulant **17**/polarizing film **11**. The differences between the first and second embodiments are the brightness enhancer **12** posted on the cathode electrode **16**, the brightness enhancer **12** encapsulated by the transparent encapsulant **17**, and the

polarizing film **11** posted on the transparent encapsulant **17**. The invention is not limited to above fabrication technologies, and other suitable methods can be used.

Since light **18** is emitted through the cathode electrode **16** of the device, substrate **13** transparent or opaque, such as glass or plastic substrate. The anode electrode **14** comprises Pt or Au metal electrode; or indium tin oxide (ITO) or indium zinc oxide (IZO) electrode with Au, Ag or Al reflective thin film. The cathode electrode **16**, transparent or semi-transparent, such as Al, Mg, Ag, Ca or alloys thereof; or indium tin oxide (ITO) or indium zinc oxide (IZO) electrode with Al, Mg, Ag, or Ca thin film. The transparent encapsulant **17** comprises transparent glass or plastic. Other materials of the device are the same as in the first embodiment.

Third Embodiment

FIG. **4** is a cross section of an OLED with a brightness enhancer according to the third embodiment of the invention. The OLED **40** has a structure comprising substrate **13**/anode electrode **14**/organic light emitting layer **15**/cathode electrode **16**/transparent encapsulant **17**/brightness enhancer **12**/polarizing film **11**. The difference between the second and third embodiments is the brightness enhancer **12** position. Other fabrication and materials of the device are the same as in the second embodiment.

ness enhancer provides a 1.5~1.7 times the brightness of OLED without the brightness enhancer.

Example 2

The fabrication method and materials of Example 2 are the same as Example 1, except the brightness enhancer **12** was synthesized by the fabrication method disclosed in U.S. Pat. No. 6,721,030, with 420~720 nm reflective wavelength range. The brightness of this example is shown in Table 1.

Example 3

The fabrication method and materials of Example 3 are the same as example 1, except the brightness enhancer **12** was synthesized by the fabrication method disclosed in U.S. Pat. No. 6,721,030, with 420~810 nm reflective wavelength range. The brightness of this example is shown in Table 1.

Comparison Example

The fabrication method and materials of the comparative Example are the same with Example 1, except there is no brightness enhancer **12** in the device. The brightness of this comparison example is shown in Table 1.

TABLE 1

Sample No.	Test angle	Brightness 1 (cd/m^2)	Brightness 2 (cd/m^2)	Brightness 3 (cd/m^2)	Brightness 4 (cd/m^2)	Average (cd/m^2)
Example 1	0°	909	917.7	921.3	912.6	915.2
	10°	925.3	934.7	932	940.9	933.2
	20°	929.6	934.4	943.5	937	936.1
	30°	851.5	859.7	830.3	834.1	843.9
Example 2	0°	741.6	743.7	744.3	733.9	740.9
	10°	745.2	756.3	755	741.3	749.5
	20°	744.9	752	753	733.1	754.8
	30°	649.3	647.4	644.1	647.5	647.1
Example 3	0°	848.6	875.2	879	884.7	871.9
	10°	851.7	887.8	890.1	899.4	882.3
	20°	848.2	881	893.6	908.6	882.9
	30°	755.4	756	772.4	798.6	770.6
Comparison Example	0°	578.9	576.6	564.3	568.2	572
	10°	582.9	569.3	563.6	563	569.7
	20°	601.2	588.5	582.5	579.6	588
	30°	567.4	561.5	549.9	550.6	557.4

Example 1

First, a glass substrate **13** was provided. 150 nm indium tin oxide (ITO) was formed on the glass substrate **13** by sputtering under 10^{-3} torr at room temperature as a transparent anode electrode **14**. 100 nm OLED material was formed on the anode electrode **14** by vacuum thermal evaporation as an organic light emitting layer **15**. 120 nm Al metal layer was formed by vacuum thermal evaporation as a cathode electrode **16**. 10 μm cholesterol liquid crystal thin film layer was post on another side of the substrate **13** as a brightness enhancer **12**. A commercially available polarizing film **11** was posted on the brightness enhancer **12**, providing OLED structure **20** of polarizing film **11**/brightness enhancer **12**/substrate **13**/anode electrode **14**/organic light emitting layer **15**/cathode electrode **16**/encapsulant (not shown).

The brightness of 0°, 10°, 20°, 30° from normal of structure **20** are shown in Table 1. This OLED with bright-

The brightness enhancer of the present invention comprises a reflective polarization transform element. The reflective polarization transform element comprises a cholesterol liquid crystal thin film layer to polarize light into left and right polarized light. The opposite optical rotation light transmits the cholesterol liquid crystal thin film layer and the same optical rotation light is reflected. The reflected light is reversed to transmitted light by the metal layer as a reflective surface of the OLED and through ¼ wavelength delay layer to emit all the interior light. The brightness of the OLED is two times that of the conventional OLED. Above examples prove the OLED has 1.6 times the brightness of conventional OLED, requiring no added power.

While the invention has been described by way of Example and in terms of preferred embodiment, it is to be understood that the invention is not limited thereto. To the contrary, it is intended to cover various modifications and similar arrangements (as would be apparent to those skilled

in the art). Therefore, the scope of the appended claims should be accorded the broadest interpretation to encompass all such modifications and similar arrangements.

What is claimed is:

1. An organic light emitting diode (OLED) with a brightness enhancer, comprising:
   - a substrate having a first surface and a second surface opposite thereto;
   - an anode electrode disposed on the first surface of the substrate;
   - an organic light emitting layer disposed on the anode electrode;
   - a cathode electrode disposed on the organic light emitting layer; and
   - a brightness enhancer disposed on the second surface of the substrate.

2. The OLED as claimed in claim 1, further comprising a polarizing film on the brightness enhancer.

3. The OLED as claimed in claim 1, wherein the substrate is transparent glass or plastic.

4. The OLED as claimed in claim 1, wherein the brightness enhancer is a reflective polarization transformation element.

5. The OLED as claimed in claim 4, wherein the brightness enhancer comprises at least a cholesterol liquid crystal thin film layer.

6. The OLED as claimed in claim 1, wherein the brightness enhancer is multilayered.

7. The OLED as claimed in claim 1, wherein the brightness enhancer comprises a film separating different polarized lights into transmitted and reflective light.

8. The OLED as claimed in claim 1, wherein the anode electrode is indium tin oxide (ITO) or indium zinc oxide (IZO).

9. The OLED as claimed in claim 1, wherein the organic light emitting layer is OLED or polymer light emitting diode (PLED).

10. The OLED as claimed in claim 1, wherein the organic light emitting layer further comprises at least one electron injection layer, an electron transfer layer, a hole injection layer and a hole transfer layer.

11. The OLED as claimed in claim 1, wherein the cathode electrode is Al, Mg, Ag, Ca or alloys thereof.

12. An organic light emitting diode (OLED) with a brightness enhancer, comprising:

   - a substrate;
   - an anode electrode disposed on the substrate;
   - an organic light emitting layer disposed on the anode electrode;
   - a cathode electrode disposed on the organic light emitting layer; and
   - a brightness enhancer disposed on the cathode electrode.

13. The OLED as claimed in claim 12, further comprising a transparent encapsulant on one the OLED top or bottom surface.

14. The OLED as claimed in claim 12, further comprising a polarizing film on the outermost OLED.

15. The OLED as claimed in claim 12, wherein the substrate is transparent or opaque glass or plastic substrate.

16. The OLED as claimed in claim 12, wherein the brightness enhancer is a reflective polarization transform element.

17. The OLED as claimed in claim 16, wherein the brightness enhancer comprises at least a cholesterol liquid crystal thin film layer.

18. The OLED as claimed in claim 12, wherein the brightness enhancer is multilayered.

19. The OLED as claimed in claim 12, wherein the brightness enhancer is a film separating different polarized light into transmitted and reflective light.

20. The OLED as claimed in claim 12, wherein the anode electrode is Pt, or Au metal electrode; or indium tin oxide (ITO) or indium zinc oxide (IZO) electrode with Au, Ag, or Al reflective layer.

21. The OLED as claimed in claim 12, wherein the organic light emitting layer is OLED or polymer light emitting diode (PLED).

22. The OLED as claimed in claim 12, wherein the organic light emitting layer further comprises at least one electron injection layer, an electron transfer layer, a hole injection layer and a hole transfer layer.

23. The OLED as claimed in claim 12, wherein the cathode electrode is Al, Mg, Mg, Ca or alloys thereof; or indium tin oxide (ITO) or indium zinc oxide (IZO) electrode with Al, Mg, Ag, or Ca thin film.

* * * * *

EXHIBIT I

US007270457B2

(12) **United States Patent**
Guo et al.

(10) **Patent No.: US 7,270,457 B2**
(45) **Date of Patent: Sep. 18, 2007**

(54) **LIGHT SOURCE DEVICE AND PROJECTOR USING THE SAME**

(75) Inventors: **Huang-Chen Guo**, Kaohsiung County (TW); **Chi-Xiang Tseng**, Kaohsiung (TW)

(73) Assignee: **Industrial Technology Research Institute**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/308,709**

(22) Filed: **Apr. 25, 2006**

(65) **Prior Publication Data**

US 2007/0103927 A1 May 10, 2007

(30) **Foreign Application Priority Data**

Nov. 8, 2005 (TW) .... 94139058 A

(51) **Int. Cl.**
F21V 8/00 (2006.01)

(52) **U.S. Cl.** **362/555**; 362/551; 362/560; 362/561

(58) **Field of Classification Search** 362/551, 362/553, 555, 558, 559, 560, 561, 580, 582, 362/236, 800; 385/146
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,956,701	B1 *	10/2005	Peterson et al.	359/618
2003/0147055	A1	8/2003	Yokoyama	353/98
2006/0062013	A1 *	3/2006	Imade	362/551
2006/0087861	A1 *	4/2006	Tessnow et al.	362/538

FOREIGN PATENT DOCUMENTS

TW	0380123 B	1/2000

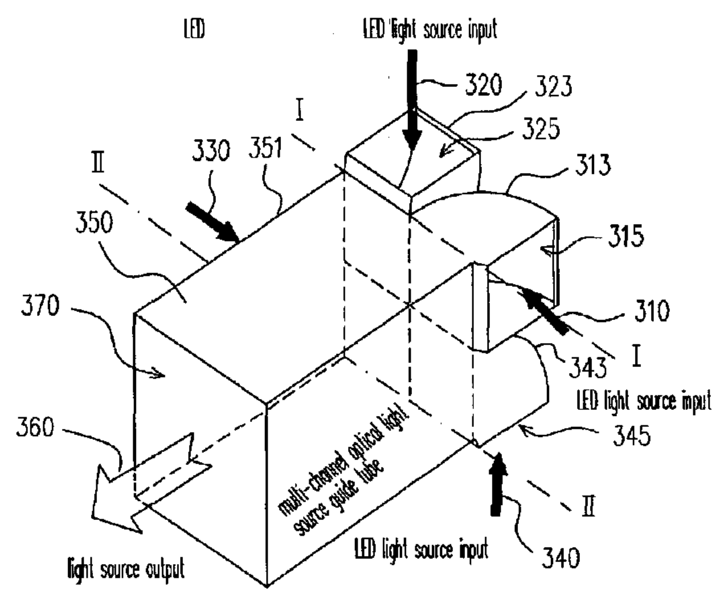
* cited by examiner

Primary Examiner—Laura Tso
(74) *Attorney, Agent, or Firm*—Jiang Chyun IP Office

(57) **ABSTRACT**

A light source device and projector using the same is provided. The light source device includes multiple light source modules and a multi-channel optical light tube. The multi-channel optical light tube includes multiple channels, each of which has a light guiding portion and corresponds to one or more of the light source modules. The light source module transmits the output light to the corresponding light channel, and the light guiding portion of each light channel is provided with a reflective surface for combining the light input through the light channels to the multi-channel optical light tube, thus providing the output of the light source device.

20 Claims, 9 Drawing Sheets



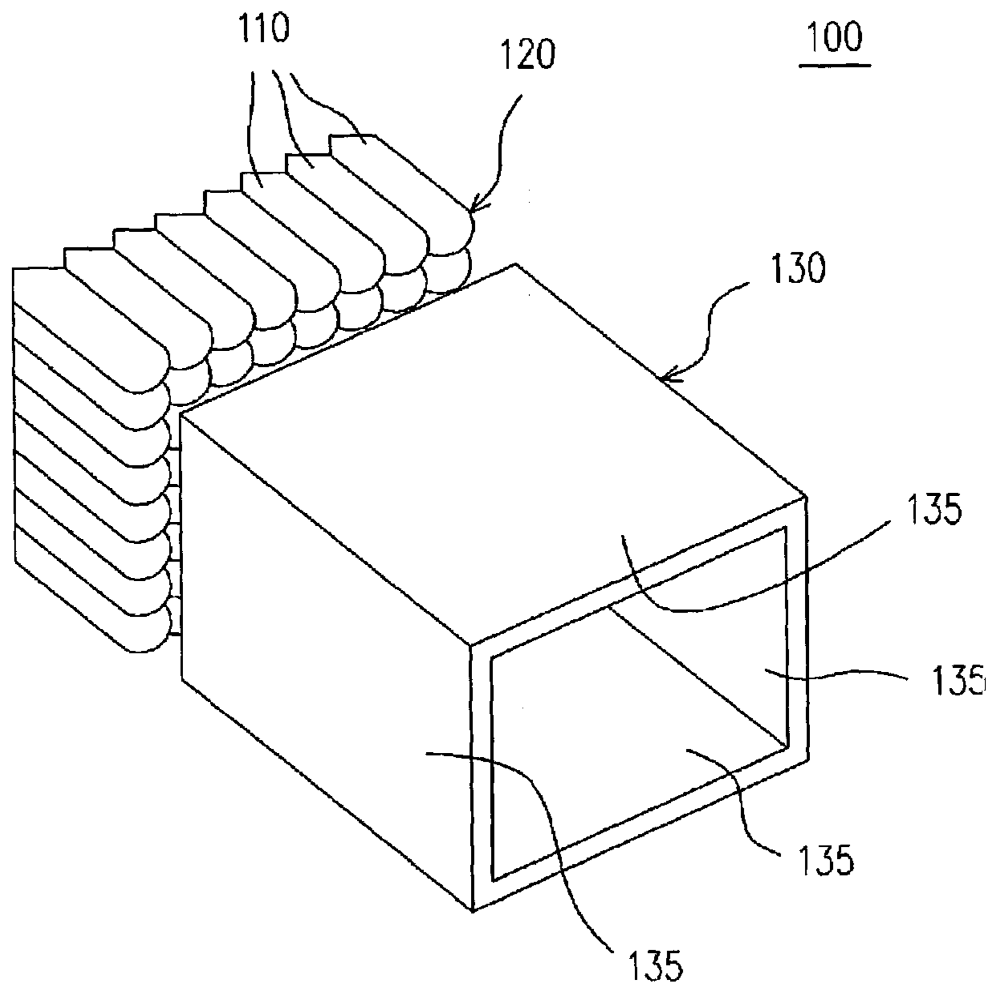


FIG. 1 (PRIOR ART)

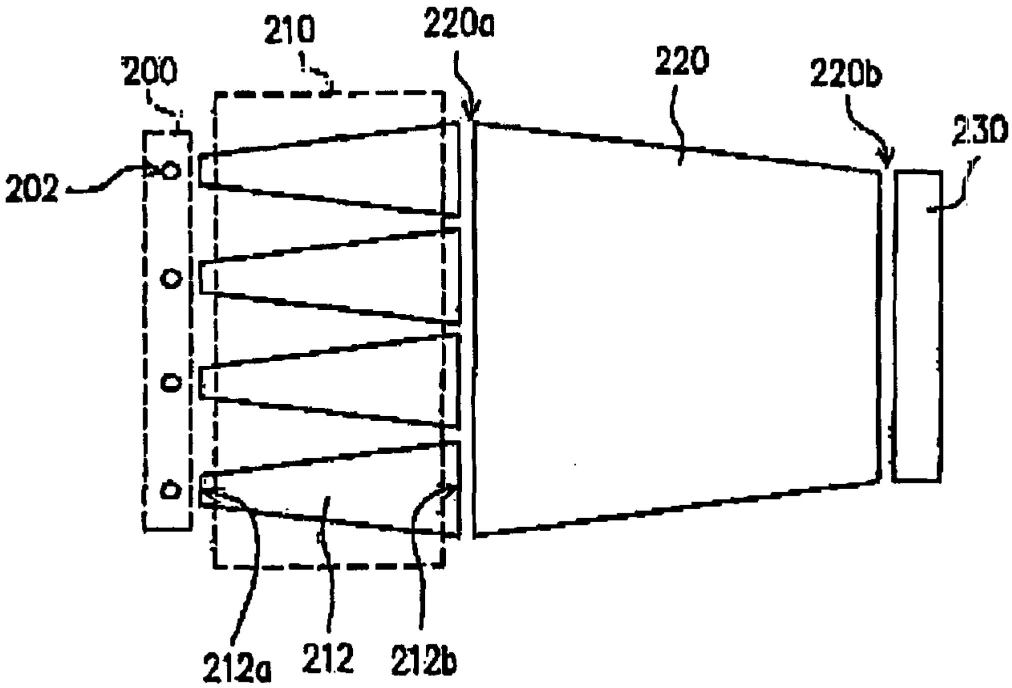


FIG. 2A (PRIOR ART)

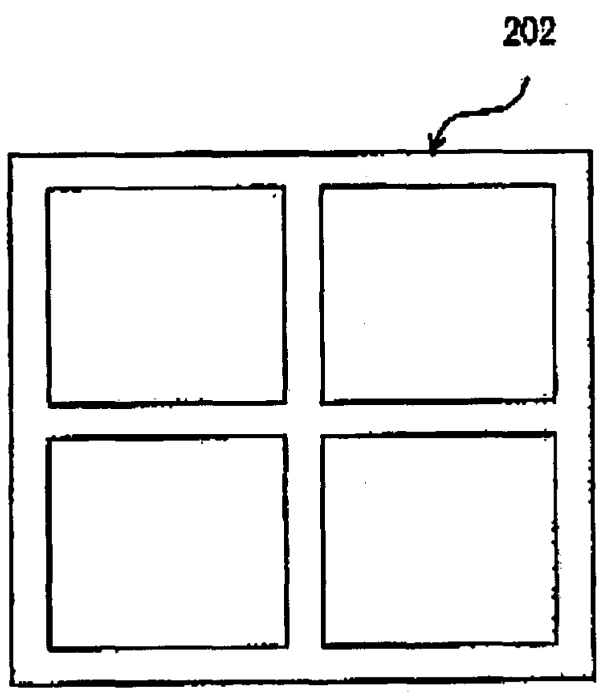


FIG. 2B (PRIOR ART)

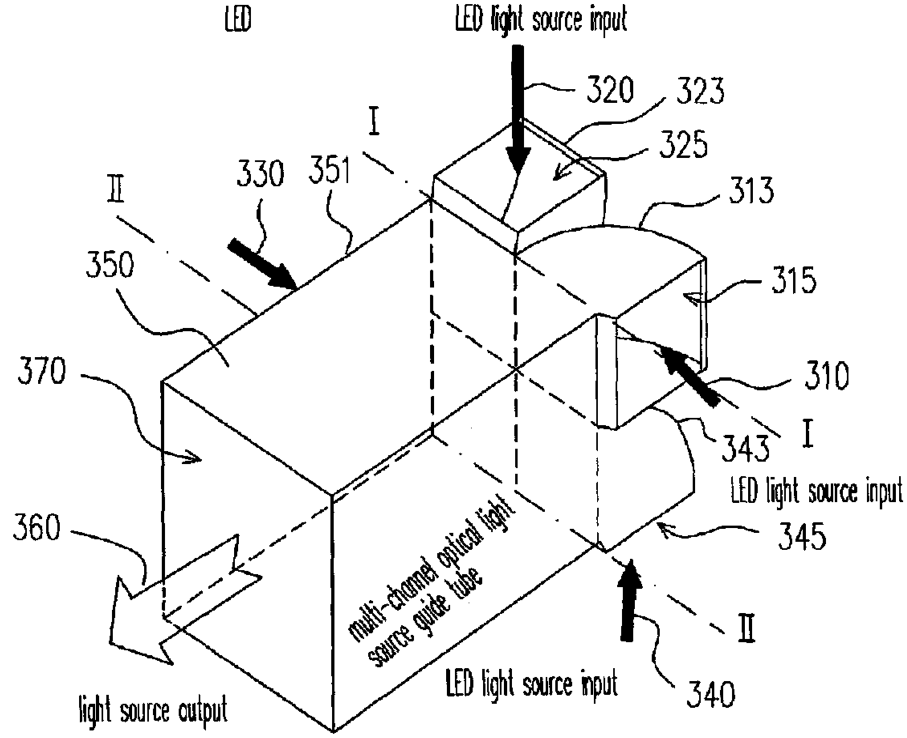
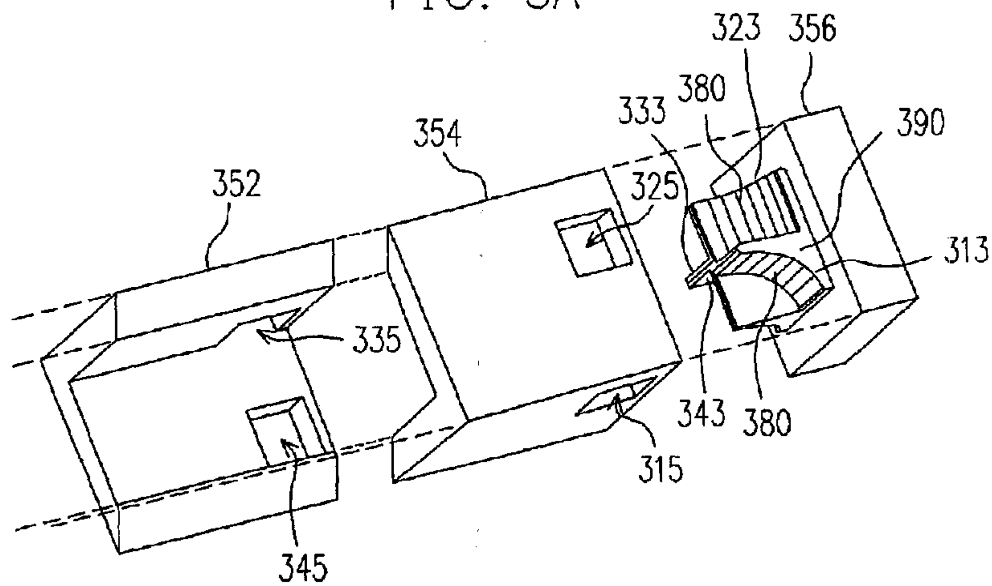

LED
LED light source input
320
323
325
313
315
310
I
II
330
351
350
370
360
343
LED light source input
345
multi-channel optical light source guide tube
LED light source input
340
light source output

FIG. 3A


323
356
380
333
390
354
325
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313
335
343
380
315
345

FIG. 3B

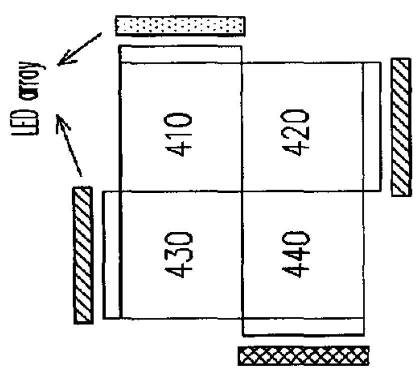

FIG. 4A

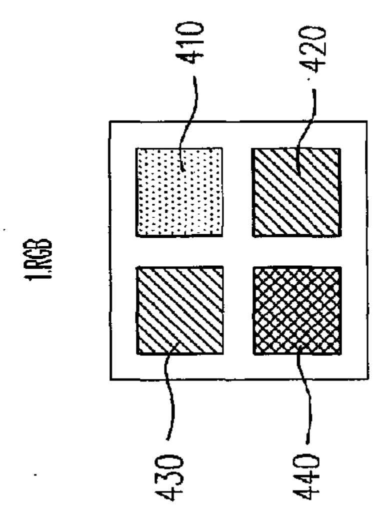

FIG. 4B

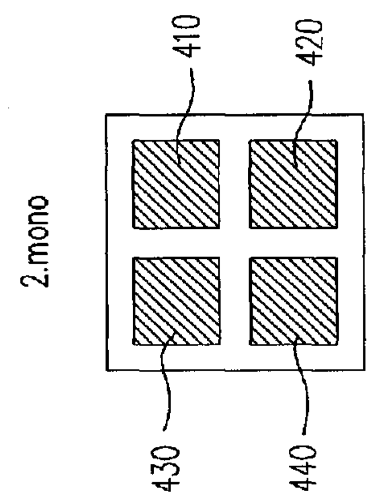

FIG. 4C

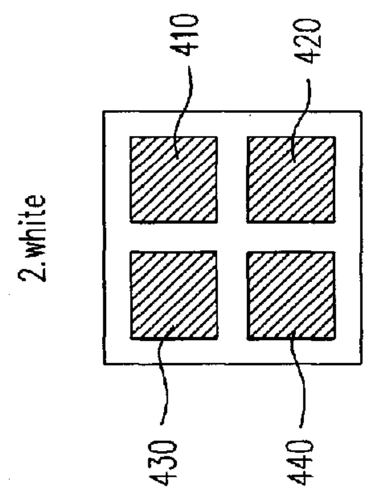

FIG. 4D

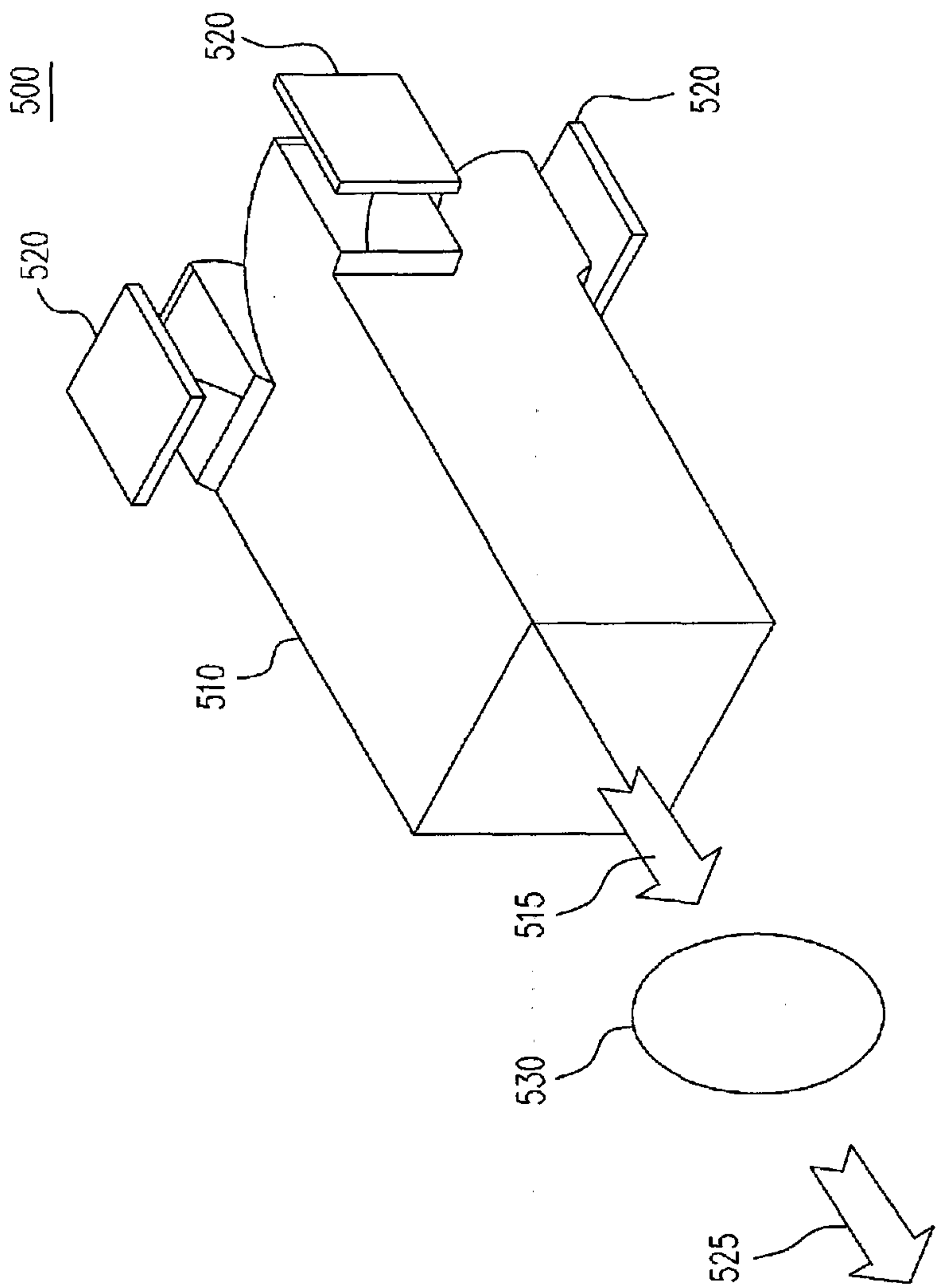

FIG. 5

53. Samsung had and continues to have actual knowledge of the '932 patent and their coverage of Samsung's infringing instrumentalities, but has nonetheless engaged in the infringing conduct. Samsung's infringement of the '932 patent was and continues to be willful.

54. As a direct and proximate result of Samsung's acts of patent infringement, ITRI has been and continues to be injured and has sustained and will continue to sustain substantial damages.

55. Unless Samsung is enjoined by this Court from continuing their infringement of the '932 patent, ITRI will suffer additional irreparable harm and impairment of the value of its patent rights.

56. ITRI has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and ITRI is entitled to recover its reasonable and necessary attorneys' fees, costs, and expenses.

VIII. INFRINGEMENT OF U.S. PATENT NO. 7,125,141

57. On October 24, 2006, the USPTO issued U.S. Patent No. 7,125,141, entitled "Apparatus for Homogeneously Distributing Lights" (hereinafter "the '141 patent"). A true and correct copy of the '141 patent is attached hereto as Exhibit F.

58. ITRI is the owner of all right, title, and interest in and to the '141 patent by assignment, with full right to bring suit to enforce the patent, including the right to recover for past infringement damages and the right to recover future royalties, damages, and income.

59. The '141 patent is valid and enforceable.

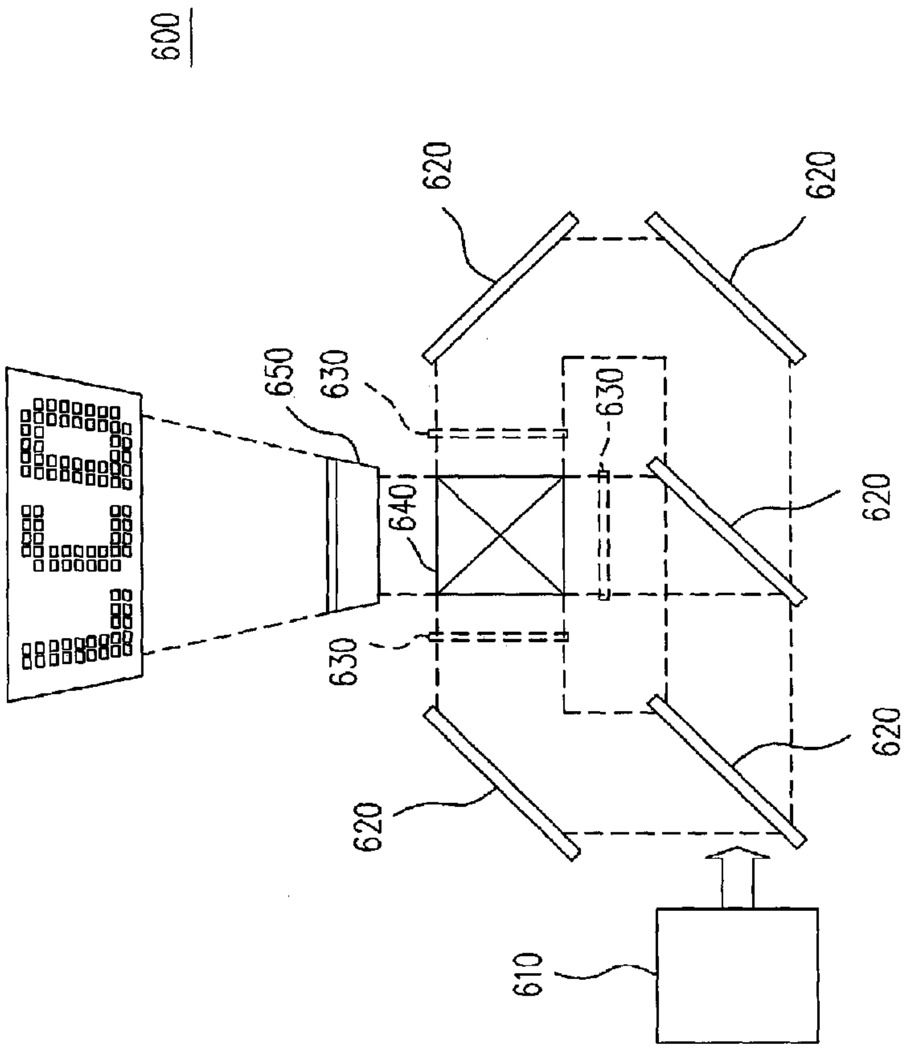

FIG. 6

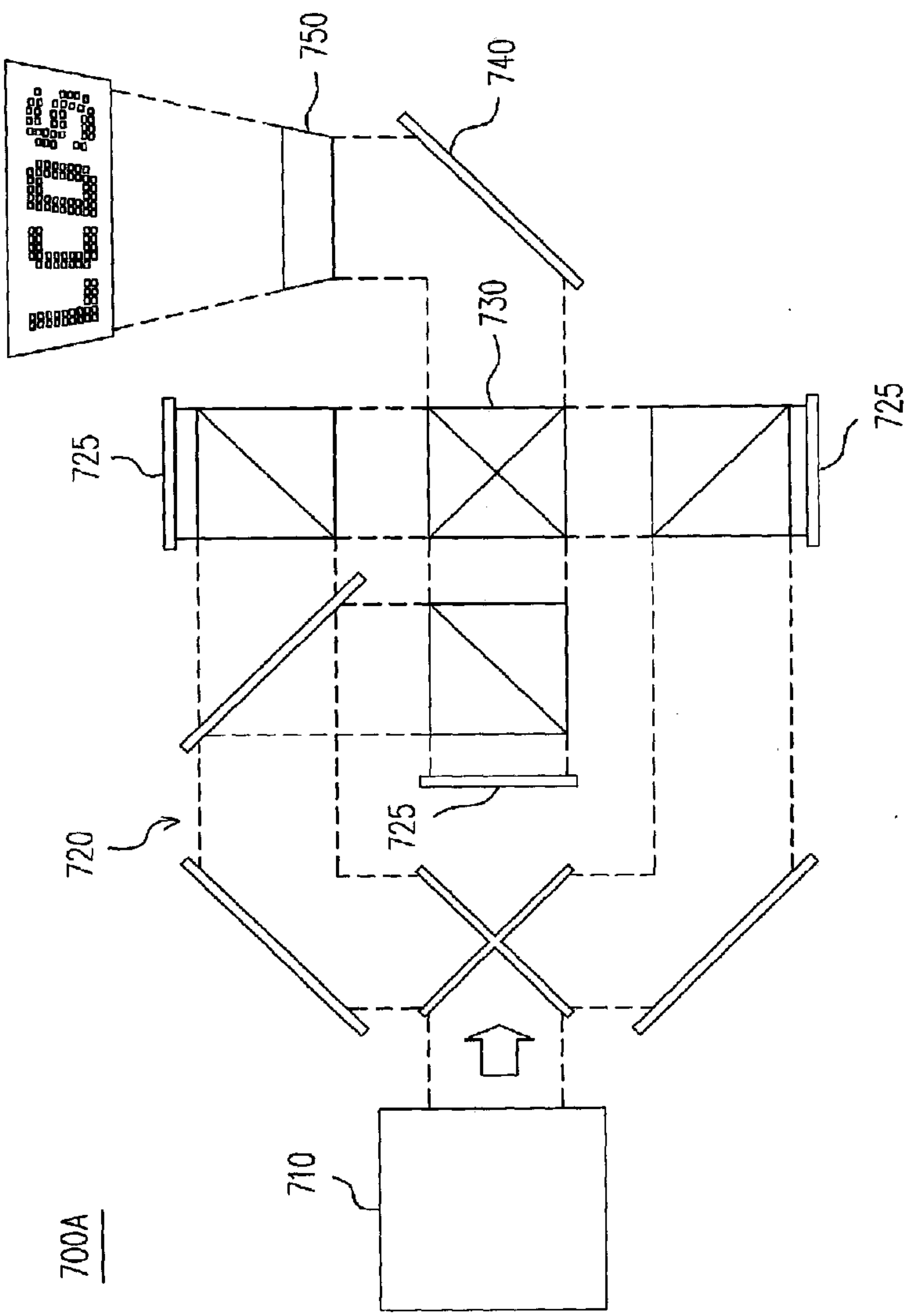

FIG. 7A

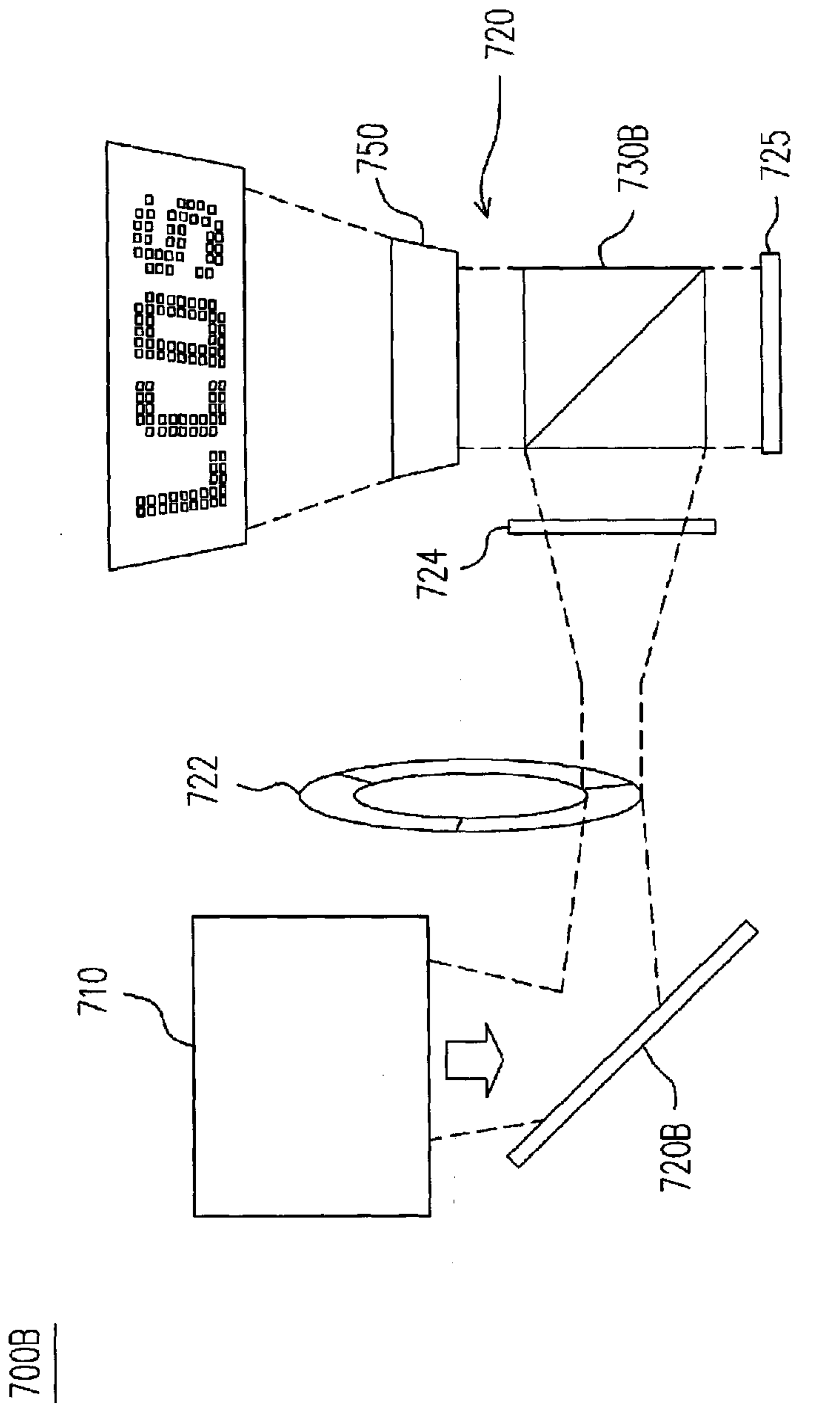

FIG. 7B

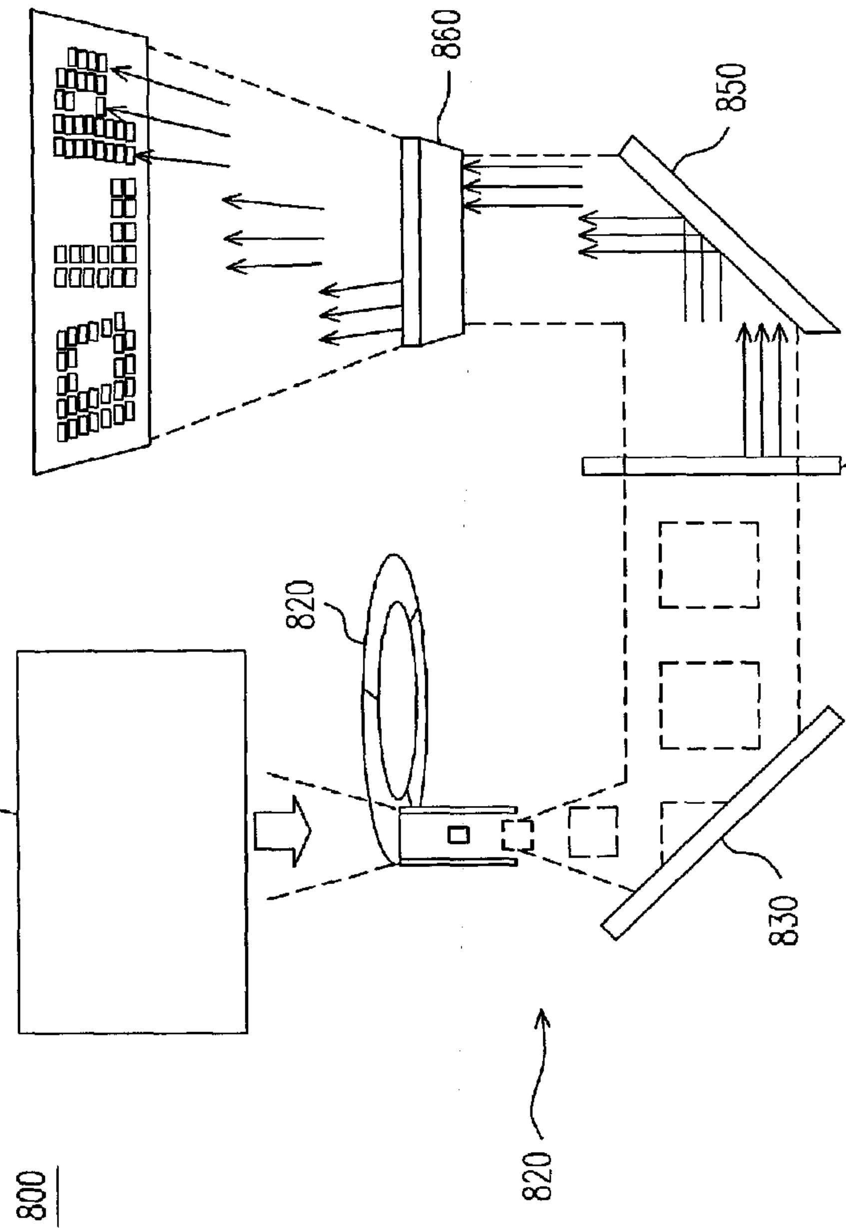

FIG. 8

LIGHT SOURCE DEVICE AND PROJECTOR USING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the priority benefit of Taiwan application serial no. 94139058, filed on Nov. 8, 2005. All disclosure of the Taiwan application is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

Furthermore, in the U.S. Pat. No. 6,318,863 of the same inventorship as the present invention, referring to FIGS. **2A** and 2B, a light source device is arranged in an array. The light source device proposed includes a light source **200**, an array of taper light pipes **210**, a taper light pipe **220**, and a light valve **230**. The light source **200** is an array of multiple light emitting modules **202**. The array of taper light pipe **210** is consisted of multiple light pipes **212**. Each of the light pipes **212** has a first end **212***a* and a second end **212***b*. The first end **212***a* of each light pipe **212** is closely connected to each light emitting module to collect the large angular beam from each light emitting module and convert the light emitted by the light source **200** into small angular light. Thereby the uniform light is emitted from the second end **212***b* of each light pipes **212**. The taper light pipe **220** has a first end **220***a* and a second end **220***b*. The first end **220***a* is used to receive the uniform light emitted from the array of taper light pipe **210** and then overlap the received light onto the light valve **230** uniformly. The structure can improve the luminance of the integral output light source.

2. Description of Related Art

Accordingly, the present invention is directed to provide a portable micro light source device, the volume of which is effectively reduced, thus presenting a better heat sinking effect and having a prolonged service life.

Furthermore, in the U.S. Pat. No. 6,318,863 of the same inventorship as the present invention, referring to FIGS. 2A and 2B, a light sources are arranged in an array. The light source device proposed includes a light source **200**, an array of taper light pipes **210**, a taper light pipe **220**, and a light valve **230**. The light source **200** is an array of multiple light emitting modules **202**. The an array of taper light pipe **210** is consisted of multiple light pipes **212**. Each of the light pipes **212** has a first end **212***a* and a second end **212***b*. The first end **212***a* of each light pipe **212** is closely connected to each light emitting module to collect the large angular beam from each light emitting module and convert the light emitted by the light source **200** into small angular light. Thereby the uniform light is emitted from the second end **212***b* of each light pipes **212**. The taper light pipe **220** has a first end **220***a* and a second end **220***b*. The first end **220***a* is used to receive the uniform light emitted from the array of taper light pipe **210** and then overlap the received light onto the light valve **230** uniformly. The structure can improve the luminance of the integral output light source.

However, if the abovementioned light source device is applied in the micro light source device, particularly in the portable micro projector, it is too large to be miniaturized. Additionally, the problem of heat sinking is not easy to be solved, thus reducing the service life of the light source.

SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to provide a portable micro light source device, the volume of which is effectively reduced, thus presenting a better heat sinking effect and having an prolonged service life.

An embodiment of the light source device proposed by the present invention includes multiple light source modules and a multi-channel optical light tube. The multi-channel optical light tube includes multiple channels, each of which has a light guiding portion and corresponds to one or more of the light source modules. The light source module transmits the output light to the corresponding light channel, and the light guiding portion of each light channel is provided with a reflective surface for combining the light input through the light channels to the multi-channel optical light tube, thus providing the output of the light source device.

The abovementioned light source device further includes a lens group for refracting or scattering the light output by the multi-channel optical light tube.

For the abovementioned light source device, the total area of the luminous flux of the light channels equals to the area of the luminous flux within the multi-channel optical light tube.

In the abovementioned light source device, the surface of the light guiding portion is designed as a curved face or an arc face.

In the abovementioned light source device, the light source modules provide different light source combinations to adjust the components of the light emitted by the light source device.

In the abovementioned light source device, the LED light source modules is an array of multiple red (R), green (G), and blue (B) LEDs, or an array of multiple single-color or white LEDs.

In the abovementioned light source device, the light source modules are Organic Light Emitting Diode (OLED) light source modules, Laser Diode light source modules, Electro-luminescence Device light source modules, Field Emission Display light source modules or Cold Cathode Fluorescence Lamp light source modules.

In the abovementioned light source device, the multi-channel optical light tube includes a heat dissipation fin for heat sinking.

The projector in one embodiment of the present invention includes a light source device and an image generating module. The light source device includes multiple light source modules and a multi-channel optical light tube. The multi-channel optical light tube includes multiple channels, each of which has a light guiding portion and corresponds to one or more of the light source modules. The light source module transmits the output light to the corresponding light channel, and each light guiding portion of each light channel is provided with a reflective surface for combining the light input through the light channels to the multi-channel optical light tube, thus providing the output of the light source device. The image generating module generates a corresponding image with the light produced by the light source device, based upon an image signal source.

The abovementioned projector further includes a heat-sink device, wherein the light source device dissipates heat through the heat-sink device.

The abovementioned projector is a LCD projector device, a single-panel or three-panel Liquid Crystal on Silicon (LCOS) projector device, or a Digital Light Processing (DLP) projector device.

In order to the make the aforementioned and other objects, features and advantages of the present invention comprehensible, a preferred embodiment accompanied with figures is described in detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view illustrating arrangement of the LED of a conventional LED projector;

FIGS. 2A and 2B illustrates the light source device arranged in an array of the conventional light source;

FIG. 3A illustrates a light source device applied in the LED projector in one embodiment of the present invention;

FIG. 3B is a schematic view illustrating the components of the light source device of the LED projector according to the preferred embodiments of FIG. 3A;

FIG. 4A is a schematic view illustrating the combinations of light source received in the light through tube inside the body of the optical light tube at the cross section between the Line I-I and Line II-II in FIG. 3A;

FIGS. 4B, 4C, and 4D illustrate the components of the light from different light channels in the cross section of FIG. 4A;

FIG. 5 illustrates a light source device applied in the LED projector according to the embodiments of the present invention;

FIG. 6 illustrates a LCD projector device employing the light source device of the preferred embodiment of the present invention;

FIG. 7A illustrates a LCOS projector device with three LCOS panels employing the light source device of the preferred embodiment of the present invention;

FIG. 7B illustrates a LCOS projector device with single LCOS panel employing the light source device of the preferred embodiment of the present invention; and

FIG. 8 illustrates a DLP projector device employing the light source device of the preferred embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

The present invention discloses a uniform light source device and a projector, which employs several light sources to achieve both uniform light and mixed light effects through the multi-channel optical light tube and the light source lens group. In addition, the area for heat sinking can be greatly expanded by using the ring-shaped and spherical light source distribution technique in the heat sinking region of the light source device, and the effect of heat sinking can be further improved by applying the heat conduction mechanism to the housing, thereby prolonging the service life of the light source. The light source device and projector can be applied to a variety of micro imaging panels, such as the Liquid Crystal Display (LED), Liquid Crystal on Silicon (LCOS) panel, and the Digital Light Processing (DLP).

The light source described above is, for example, a Light Emitting Diode (LED), an Organic Light Emitting Diode (OLED), a Laser Diode (LD), an Electro-luminescence Device (EL), a Field Emission Display (FED) or a Cold Cathode Fluorescence Lamp (CCFL) or the like. Each of the channel optical light tubes can be applied with one light source, or a plurality of light sources, according to design desired. In addition, if the plurality of light sources are implemented herein, an arrangement of the light sources can also be configured for performance.

To detail the features of the present invention, the application of the LED projector in an embodiment below is

taken for the purpose of illustration, but it does not mean that the present invention is limited to the light source device and projector of the LED.

Referring to FIG. 3A, it shows a light source device applied in the LED projector in one embodiment of the present invention. FIG. 3B is a schematic view illustrating the components of the light source device of the LED projector according to a preferred embodiment in FIG. 3A. The embodiment of the present invention is illustrated according to FIGS. 3A and 3B. In the multi-channel light source device of the present invention, lights of the multiple small channels are collected and then combined into the total light of a large light through tube, thus achieving uniform and mixed light effects at the same time.

Firstly, different LED lights, such as the LED light source inputs **310**, **320**, **330**, and **340** in FIG. 3A, are input to the multi-channel optical light guide tube **350** via input holes **315**, **325**, **335**, and **345** respectively. The input hole **335** is shown in FIG. 3B. The total cross-section area of the input holes **315**, **325**, **335**, and **345** is equal to or approximate to the area of the cross section between Line I-I and Line II-II of the body **351** of the multi-channel optical light guide tube **350**. Of course, in an alternative embodiment, it is unnecessary that the total cross-section area of the input holes **315**, **325**, **335**, and **345** equals to the area of the cross section of the guide tube body **351** of the multi-channel optical light guide tube **350**, as long as a proper adjustment is made.

After being input through the input holes **315**, **325**, **335**, and **345** respectively, lights from the LED light source inputs **310**, **320**, **330**, and **340** are reflected to the interior of the guide tube body **351** of the multi-channel optical light source guide tube **350**, through light channels respectively formed by light guiding portions **313**, **323**, **333**, and **343**, and then an uniform and mixed light **360** is output via an output hole **370**. In one embodiment, the LED light source inputs can be applied with one LED light source, or a plurality of LED light sources, according to design desired. In addition, if the plurality of LED light sources are implemented herein, an arrangement of the LED light sources can also be configured for performance. According to an optical invariance principle, a total area of luminous flux of the light channels formed by the light guiding portions **313**, **323**, **333**, and **343** equals to an area of luminous flux of a light guiding portion formed by the guide tube body **351**. The light guiding portions **313**, **323**, **333**, and **343** are designed as curved faces or arc faces. A light reflective surface **380** is provided inside the curved face or the arc face of each light guiding portion **313**, **323**, **333** or **343**. The light reflective surface **380** is formed by, for example, coating a layer of silver or other materials having reflective effect on the surface, for reflecting the incident light.

If the light source required by the projector is the three primary colors (i.e. red, green and blue, respectively denoted as "R", "G" and "B", hereinafter), the light source can be divided as RGGB, i.e. the light entering the position **410** is set to be red, and the light entering the positions **420** and **430** is set to be green, and the light entering the position **440** is set to be blue, as shown in FIG. 4B. Of course, the arrangement of the colors of the incoming light can be modified according to the required application, but is not limited thereto. Assuming that the light source required by the projector is mono, the light at the positions **410-440** is set to be the mono light, as shown in FIG. 4C. Assuming that the light source required by the projector is white, the light at the positions **410-440** is set to be white, as shown in FIG. 4D. For the light source device proposed by the present invention, the light source can employ the LED modules that

include the combinations of several R, G, B or other color LEDs, or an array of mono LED, or the like. With such design, the electronic device of the light source device of the present invention, such as the projector, can provide light sources of different characteristics as desired.

In addition, the multi-channel optical light guide tube **350** can also be connected to a heat conduction or heat-sink device that is an original heat dissipation structure of the LED light source, or an additional heat dissipation fin for increasing the heat sinking area and the heat sinking efficiency. In an alternative embodiment, a fan is further used to control the heat flow, facilitating the overall heat sinking effect.

For the light source device applied in the LED projector according to the embodiment of the present invention, a portion of the uniform and mixed light effects is shown in FIG. **4A** that is a schematic view illustrating the combinations of the light source received in the light through tube inside the guide tube body **351** of the multi-channel optical light guide tube **350** at the cross section between Lines I-I and II-II in FIG. 3A. Herein, it is assumed that the light introduced by the light guiding portions **313**, **323**, **333**, and **343** are positioned at positions **410**, **420**, **430**, and **440** respectively, in which the light is provided by different LED light sources. The design of different LED light sources proposed by the present invention refers to disposing the LED light sources at different positions rather than disposing together at the same position as the conventional art, such that a heat sinking mechanism is formed, thus prolonging the service life of the LED greatly and improving the overall light emitting efficiency. Moreover, based upon the demand for miniaturization, the volume of the LED light emitting modules can be controlled more efficiently to fit the portable micro projector.

If the light source required by the projector is the three primary colors (i.e. red, green and blue, respectively denoted as "R", "G" and "B", hereinafter), the light source can be divided as RGGB, i.e. the light entering the position **410** is set to be red, and the light entering the positions **420** and **430** is set to be green, and the light entering the position **440** is set to be blue, as shown in FIG. 4B. Of course, the arrangement of the colors of the incoming light can be modified according to the required application, but is not limited thereto. Assuming that the light source required by the projector is mono, the light at the positions **410-440** is set to be the mono light, as shown in FIG. **4B**. Assuming that the light source required by the projector is white, the light at the positions **410-440** is set to be white, as shown in FIG. **4C**. For the light source device proposed by the present invention, the light source can employ the LED modules that include the combinations of several R, G, B or other color LEDs, or an array of mono LED, or the like. With such design, the electronic device of the light source device of the present invention, such as the projector, can provide light sources of different characteristics as desired.

Referring to FIG. **5**, the light source device for the LED projector of the present embodiment is the LED light source device **500** mainly including the LED array **520** associated with the small channels, a multi-channel optical light guide tube **510** and a lens unit **530**. The present embodiment employs the LED array to produce a desired light source. However, it is known to those skilled in the art that the light source can be replaced by any light source which can produce the desired light. The joining relation between the LED array **520** and the corresponding small channel formed by the light guiding portions can be close connection or separated by a small pitch depending on the requirement of the application. The light **515** emitted by the multi-channel optical light guide tube **510** has the uniform and mixed light effect, and can be converted into the desired beam **525** through the lens unit **530**.

Referring to FIG. 7B, it is a schematic view mainly illustrating the LCOS projector device **700B** employing the light source devise of the preferred embodiment of the present invention. The LCOS projector devise **700B** has a single LCOS panel **725** and uses the light source device of the present invention. The light source of the light source device **710** is, for example, a LED light source. The incoming light is reflected by the reflective lens **720B** to the color drum wheel **722** having multiple different filtering regions. As such, the incident light can contact the filtering regions in different positions through the rotation of the color drum wheel **722**, so that the three primary colors(red, green and blue) can be separated. And then the separated lights transmitted to the corresponding LCOS panel **725** through the polarizing plate **724** and the polarizing beam splitter **730B**. Subsequently, the produced full-color image passing through the polarizing beam splitter **730B** is finally transmitted to the display screen via the projecting lens **750**.

The present invention is illustrated by taking the projector of the light source device of the present invention as an example, but is not limited to it.

Referring to FIG. **6**, it is a schematic view mainly illustrating the LCD projector device **600** employing the light source device of the preferred embodiment of the present invention. The LCD projector device **600** employs the light source device **610** of the present invention, and the light source of the light source device **610** is, for example, a LED light source. The three primary colors (red, green and blue) can be separated when the incoming light passes through a dichroic mirror **620**, and then transmitted to the corresponding LCD panel **630**. Subsequently, after combining the produced three-primary-color image through the combining prism **640**, a full-color image is generated and then transmitted to the display screen via the projecting lens **650**.

Referring to FIG. 7A, it is a schematic view mainly illustrating the LCOS projector device **700A** employing the light source device of the preferred embodiment of the present invention. The LCOS projector device **700A** has three LCOS panels **725** and employs the light source device **710** of the present invention. The light source of the light source device **710** is, for example, a LED light source. The three primary colors (red, green and blue) can be separated, and then transmitted to the corresponding LCOS panel **725** when the incoming light passes through several dichroic mirror groups **720**. Subsequently, after combining the produced three-primary-color image through the combining prism **730**, a full-color image is generated and then transmitted to the display screen through the reflective lens **740** and the projecting lens **750**.

Referring to FIG. 7B, it is a schematic view mainly illustrating the LCOS projector device **700A** employing the light source device of the preferred embodiment of the present invention. The LCOS projector device **700A** has a single LCOS panel **725** and uses the light source device **710** of the present invention. The light source of the light source device **710** is, for example, a LED light source. The incoming light is reflected by the reflective lens **720B** to the color drum wheel **722** having multiple different filtering regions. As such, the incident light can contact the filtering regions in different positions through the rotation of the color drum wheel **722**, so that the three primary colors(red, green and blue) can be separated. And then the separated lights are transmitted to the corresponding LCOS panel **725** through

the polarizing plate **724** and the polarizing beam splitter **730B**. Subsequently, the produced full-color image passing through the polarizing beam splitter **730B** is finally transmitted to the display screen via the projecting lens **750**.

Referring to FIG. **8**, it is a schematic block diagram mainly illustrating the DLP projector device **800** employing the light source device of the preferred embodiment of the present invention. The DLP projector device **800** has a Digital Micro-Mirror Device (DMD) **850**, and employs the light source device **810** of the present invention. The light source of the light source device **810** is, for example, a LED light source.

The incoming light passes through the color wheel **820** having multiple different filtering regions at first. As such, the incident light can contact the filtering regions in different positions through the rotation of the color wheel **820**, so that the three primary colors (red, green and blue) can be separated. And then, after passing through the reflective lens **830** and the polarizing plate **840** and being transmitted to the DMD **850**, the separated light are transmitted to the projecting lens **860** and then to the display screen after going through a digital optical processing.

The light source device and the projector disclosed by the present invention can be used to achieve the uniform light and mixed light effects, by several light sources passing through the multi-channel optical light tube and the light source lens groups. Additionally, the area for heat sinking can be greatly expanded by applying the light source distribution technique to the heat sinking region of the light source device, and the effect of heat sinking can be further improved by applying the heat conduction mechanism to the housing, thus prolonging the service life of the light source device.

The present invention has been disclosed above in the preferred embodiments, but is not limited to those. It is known to persons skilled in the art that some modifications and innovations may be made without departing from the spirit and scope of the present invention. Therefore, the scope of the present invention should be defined by the following claims.

What is claimed is:

1. A light source device, comprising:

a plurality of light source modules configured for outputting light; and

a multi-channel optical light guide tube having a plurality of light channels and a plurality of holes communicating with the channels respectively, each of the light channels having a light guiding portion and corresponding to one of the light source modules, wherein the light source module transmits the output light to the corresponding light channel via the corresponding hole, and the light guiding portion of each of the light channels is provided with a reflective surface for combining the light input through the light channels to the multi-channel optical light guide tube, thus providing the output of the light source device.

2. The light source device as claimed in claim **1**, further comprising a lens group for refracting or scattering the light output by the multi-channel optical light guide tube.

3. The light source device as claimed in claim **1**, wherein a total area of luminous flux of the light channels equals to an area of the luminous flux within the multi-channel optical light guide tube.

4. The light source device as claimed in claim **1**, wherein the surface of the light guiding portion is a curved face.

5. The light source device as claimed in claim **1**, wherein the surface of the light guiding portion is an arc face.

6. The light source device as claimed in claim **1**, wherein the light source modules provide different light source combinations to adjust components of the light output by the light source device.

7. The light source device as claimed in claim **1**, wherein the light source modules are light emitting diode (LED) light source modules.

8. The light source device as claimed in claim **7**, wherein the LED light source modules comprise an array of a plurality of red (R), green (G) and blue (B) LEDs.

9. The light source device as claimed in claim **7**, wherein the LED light source modules comprise an array of a plurality of single-color LEDs.

10. The light source device as claimed in claim **7**, wherein the LED light source modules comprise an array of a plurality of white LEDs.

11. The light source device as claimed in claim **1**, wherein the light source modules are Organic Light Emitting Diode light source modules, Laser Diode light source modules, Electro-luminescence Device light source modules, Field Emission Display light source modules or Cold Cathode Fluorescence Lamp light source modules.

12. A projector, comprising a light source device, the light source device comprising:

a plurality of light source modules configured for outputting light; and

a multi-channel optical light tube having a body and a plurality of hollow light channels surrounded by the body, each of the light channels having a light guiding portion and corresponding to one or mare of the light source modules, wherein the light source module transmits the output light to the corresponding light channel, and the light guiding portion of each of the light channels is provided with a curved reflective surface for combining the light input through the light channels to the multi-channel optical light tube, thus providing the output of the light source device; and

an image generating module for generating a corresponding image with the light produced by the light source device, based upon an image signal source.

13. The projector as claimed in claim **12**, wherein the light source modules are LED light source modules.

14. The projector as claimed in claim **12**, wherein the projector is a liquid crystal display (LCD) projector device.

15. The projector as claimed in claim **12**, wherein the projector is a liquid crystal on silicon (LCOS) projector device having a single LCOS panel.

16. The projector as claimed in claim **12**, wherein the projector is a liquid crystal on silicon (LCOS) projector having three LCOS panels.

17. The projector as claimed in claim **12**, wherein the projector is a digital light processing (DLP) projector device.

18. A light source device, comprising:

a plurality of light source modules configured for outputting light; and

a multi-channel optical light guide tube having a body and a plurality of channels surrounded by the body which defines a plurality holes communicating with the channels respectively, each of the light channels having a light guiding portion and corresponding to at least one of the light source modules, wherein the at least one light source module transmits the output light to the corresponding light channel via the corresponding hole, and the light guiding portion of each of the light

channel is provided with a curved reflective surface for combining the light input through the light channels to the multi-channel optical light guide tube, thus providing the output of the light source device.

19. The light source device as claimed in claim **18**, further comprising a lens group for refracting or scattering the light output by the multi-channel optical light guide tube.

20. The light source device as claimed in claim **18**, wherein a total area of luminous flux of the light channels equals to an area of the luminous flux within the multi-channel optical light guide tube.

* * * * *

EXHIBIT J

60. All requirements under 35 U.S.C. § 287 have been satisfied with respect to the '141 patent.

61. Samsung has been and is infringing the '141 patent by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '141 patent, including but not limited to Samsung products bearing flat panel displays such as the Samsung display LN40A630M1F.

62. Samsung has been and is continuing to induce infringement of the '141 patent under 35 U.S.C. § 271(b) and contributes to the infringement of the '141 patent under 35 U.S.C. § 271(c), in conjunction with such acts of making, using, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '141 patent. The infringing instrumentalities have no substantial non-infringing uses.

63. Samsung had and continues to have actual knowledge of the '141 patent and their coverage of Samsung's infringing instrumentalities, but has nonetheless engaged in the infringing conduct. Samsung's infringement of the '141 patent was and continues to be willful.

64. As a direct and proximate result of Samsung's acts of patent infringement, ITRI has been and continues to be injured and has sustained and will continue to sustain substantial damages.

65. Unless Samsung is enjoined by this Court from continuing their infringement of the '141 patent, ITRI will suffer additional irreparable harm and impairment of the value of its patent rights.

US007339197B2

(12) **United States Patent**
Lin et al.

(10) **Patent No.: US 7,339,197 B2**
(45) **Date of Patent: Mar. 4, 2008**

(54) **LIGHT EMITTING DIODE AND FABRICATION METHOD THEREOF**

(75) Inventors: **Chao-Ying Lin**, Taipei (TW); **Sun-Bin Yin**, Hsinchu (TW); **Sheng-Bang Huang**, Changhua (TW); **Pei-Fang Chiang**, Hsinchu (TW)

(73) Assignee: **Industrial Technology Research Institute**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 176 days.

(21) Appl. No.: **11/042,116**

(22) Filed: **Jan. 26, 2005**

(65) **Prior Publication Data**

US 2006/0054904 A1 Mar. 16, 2006

(30) **Foreign Application Priority Data**

Sep. 14, 2004 (TW) .... 93127740 A

(51) **Int. Cl.**
H01L 33/00 (2006.01)

(52) **U.S. Cl.** **257/95**; 257/E33.067; 438/27

(58) **Field of Classification Search** 257/95, 257/E33.067, E33.071, E33.074; 438/27, 438/28

See application file for complete search history.

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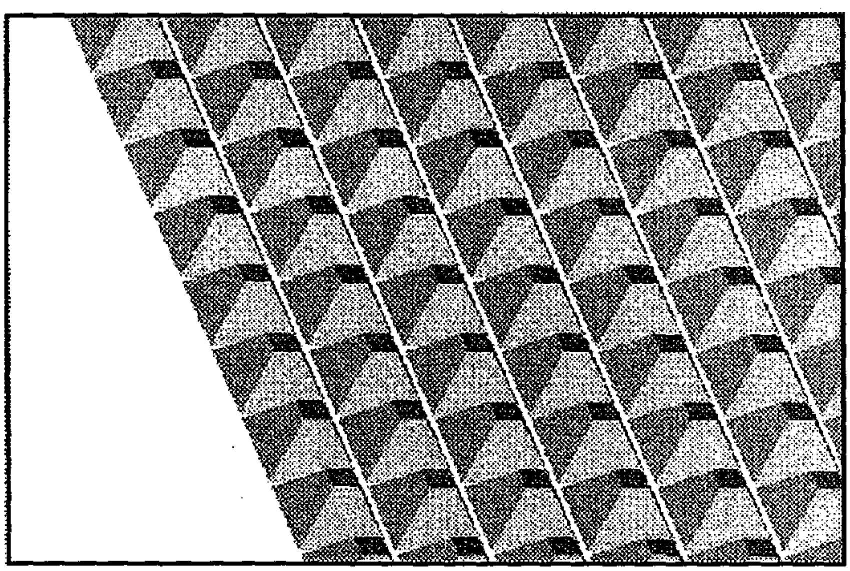
Assistant Examiner—Jennifer M. Dolan
(74) *Attorney, Agent, or Firm*—Birch, Stewart, Kolasch & Birch, LLP

(57) **ABSTRACT**

A light emitting diode. The light emitting diode comprises a lead frame, a plurality of light emitting chips in the lead frame, and a molding unit in an optical path of the light emitting chips, wherein the molding unit comprises a periodic microstructure.

25 Claims, 16 Drawing Sheets
(8 of 16 Drawing Sheet(s) Filed in Color)



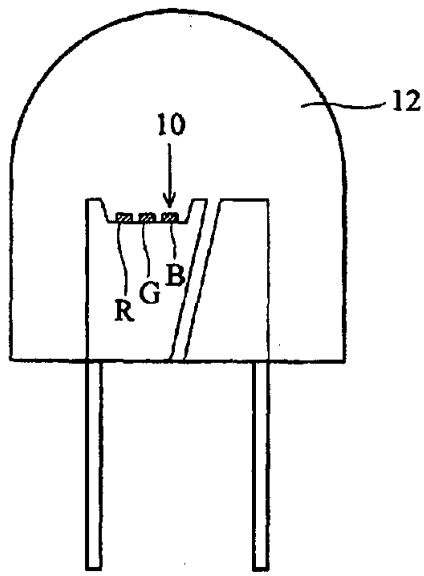


FIG. 1 (RELATED ART)

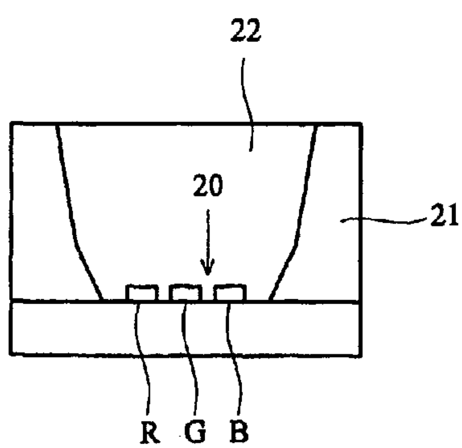


FIG. 2 (RELATED ART)

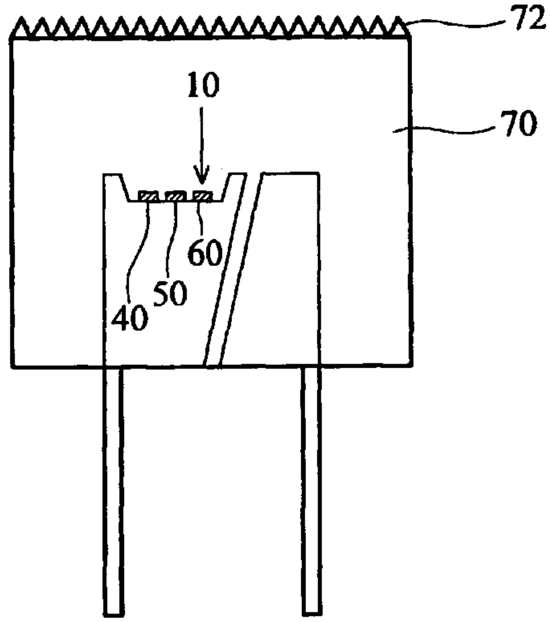


FIG. 3A

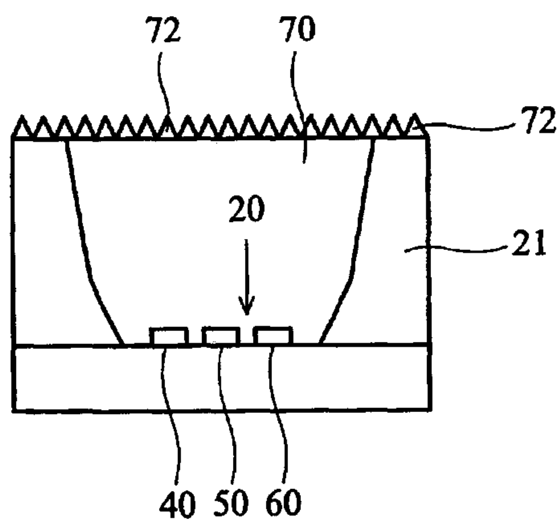


FIG. 3B

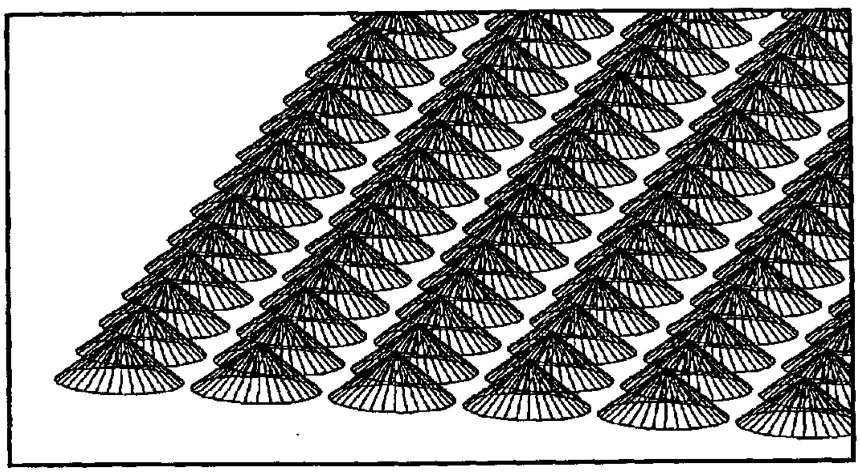


FIG. 4A

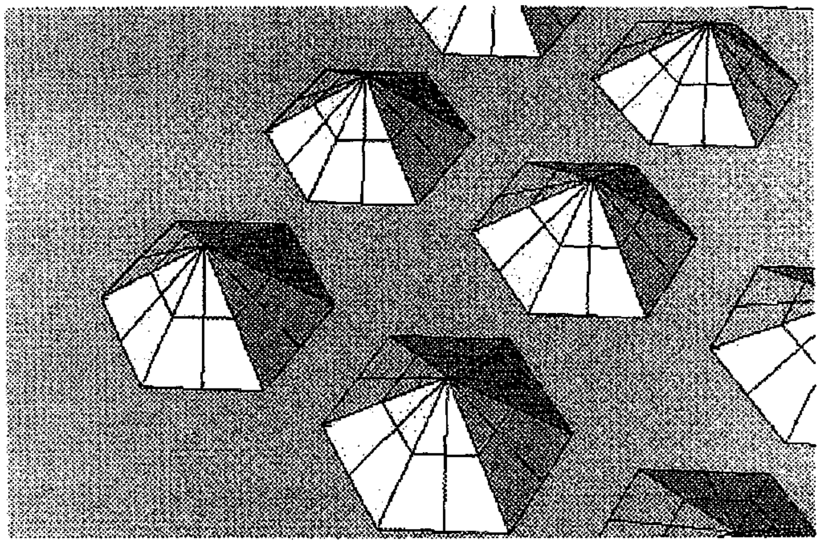


FIG. 4B

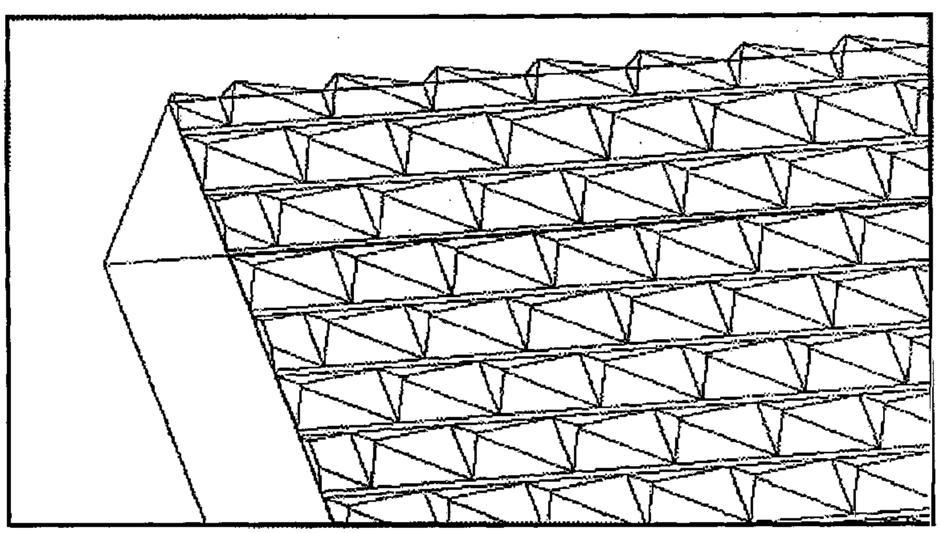


FIG. 4C

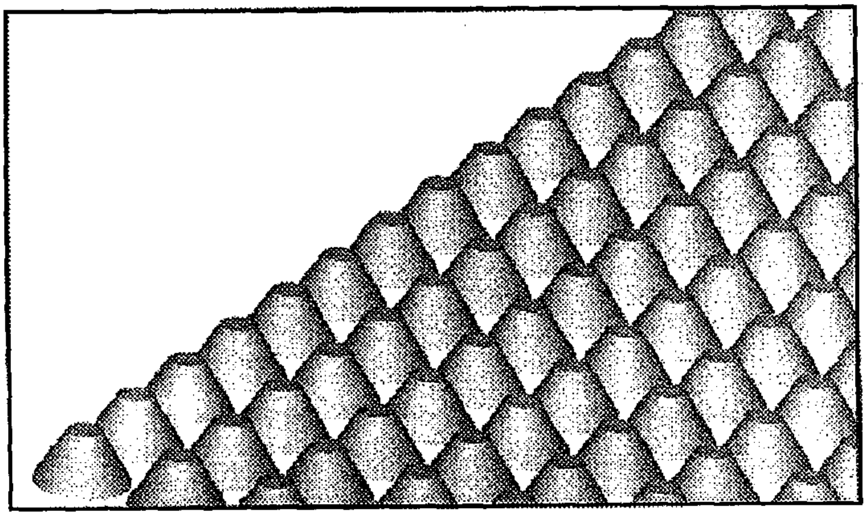


FIG. 4D

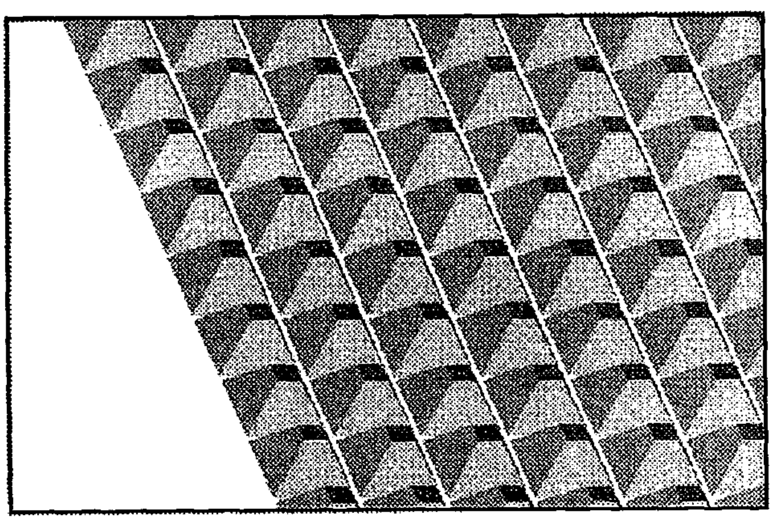


FIG. 4E

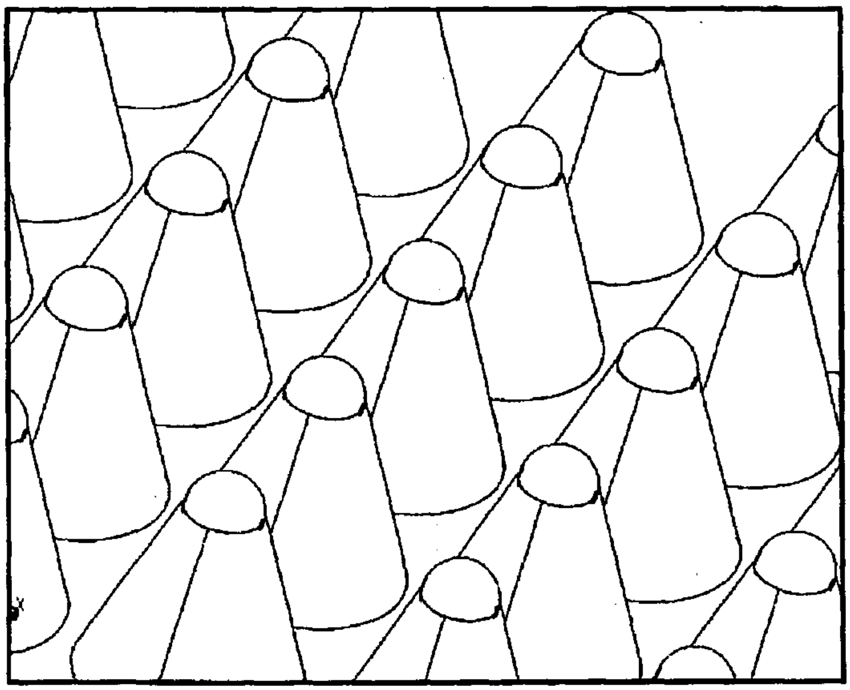


FIG. 4F

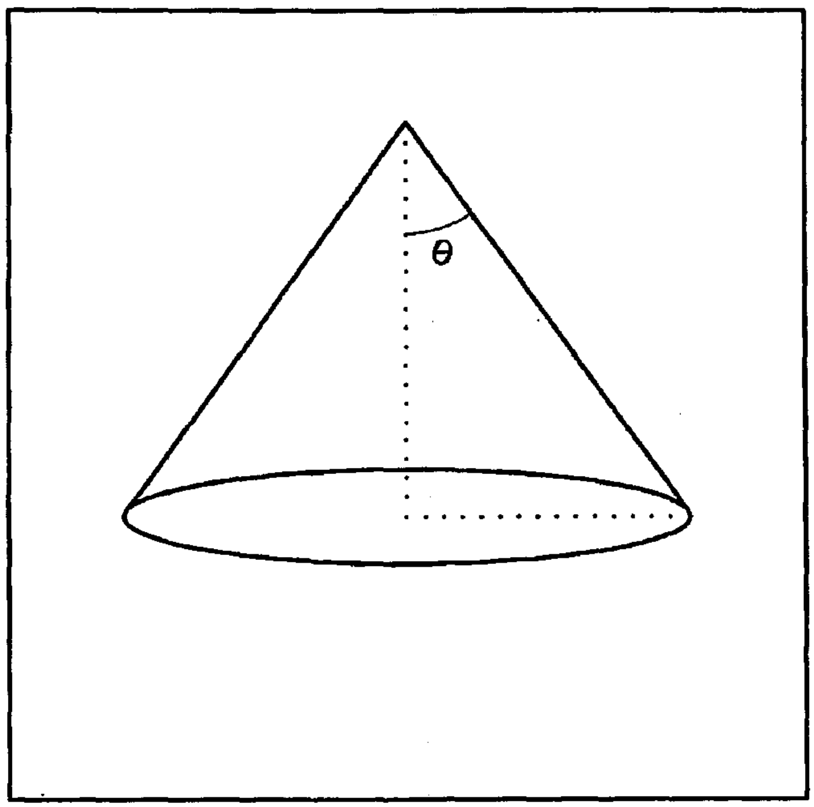
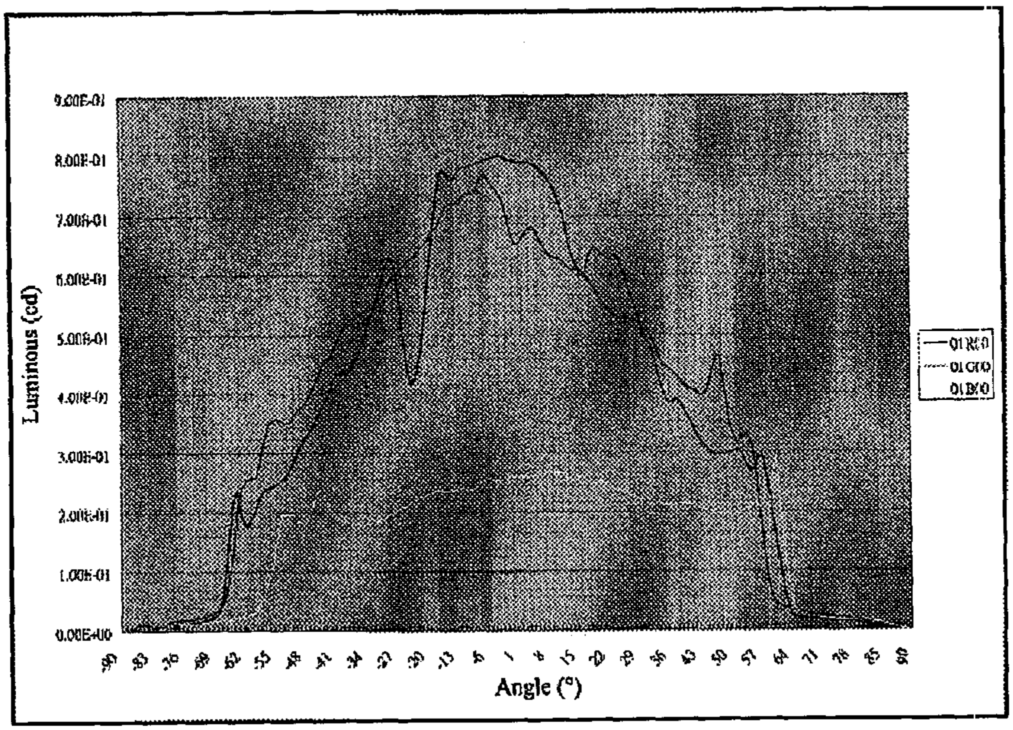


FIG. 5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0.00E+00
Luminous (cd)
Angle (°)

FIG. 6A

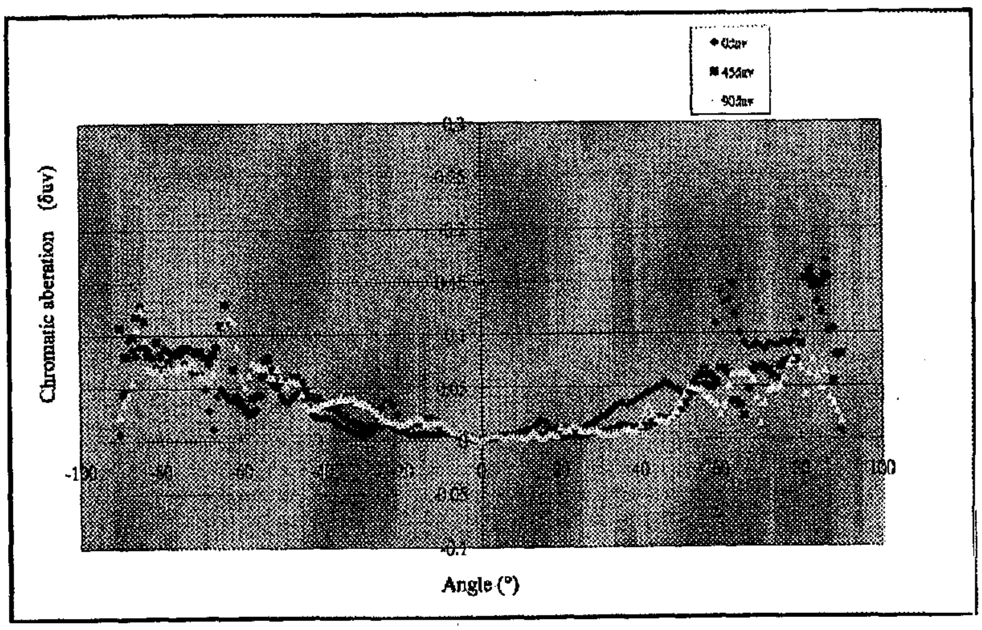


FIG. 6B

66. ITRI has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and ITRI is entitled to recover its reasonable and necessary attorneys' fees, costs, and expenses.

IX. INFRINGEMENT OF U.S. PATENT NO. 7,217,010

67. On May 15, 2007, the USPTO issued U.S. Patent No. 7,217,010, entitled "Reflector with Negative Focal Length" (hereinafter "the '010 patent"). A true and correct copy of the '010 patent is attached hereto as Exhibit G.

68. ITRI is the owner of all right, title, and interest in and to the '010 patent by assignment, with full right to bring suit to enforce the patent, including the right to recover for past infringement damages and the right to recover future royalties, damages, and income.

69. The '010 patent is valid and enforceable.

70. All requirements under 35 U.S.C. § 287 have been satisfied with respect to the '010 patent.

71. Samsung has been and is infringing the '010 patent by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '010 patent, including but not limited to Samsung products bearing flat panel displays such as the Samsung netbook NP-N310-KA04US and notebook X460-41S.

72. Samsung has been and is continuing to induce infringement of the '010 patent under 35 U.S.C. § 271(b) and contributes to the infringement of the '010 patent under 35 U.S.C. § 271(c), in conjunction with such acts of making, using, offering for

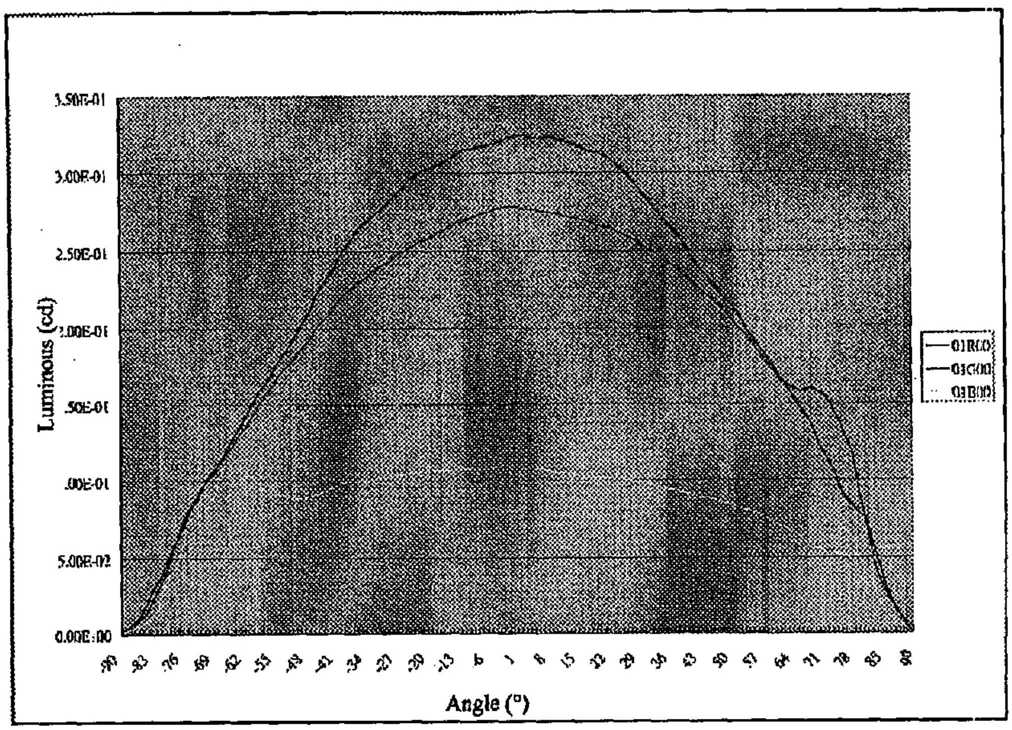


FIG. 7A

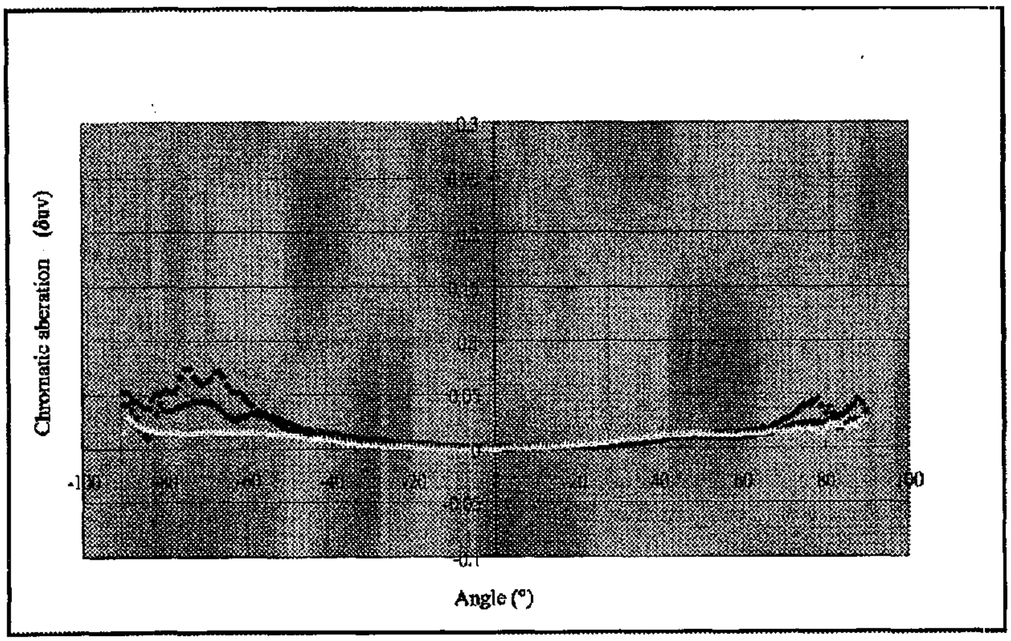


FIG. 7B

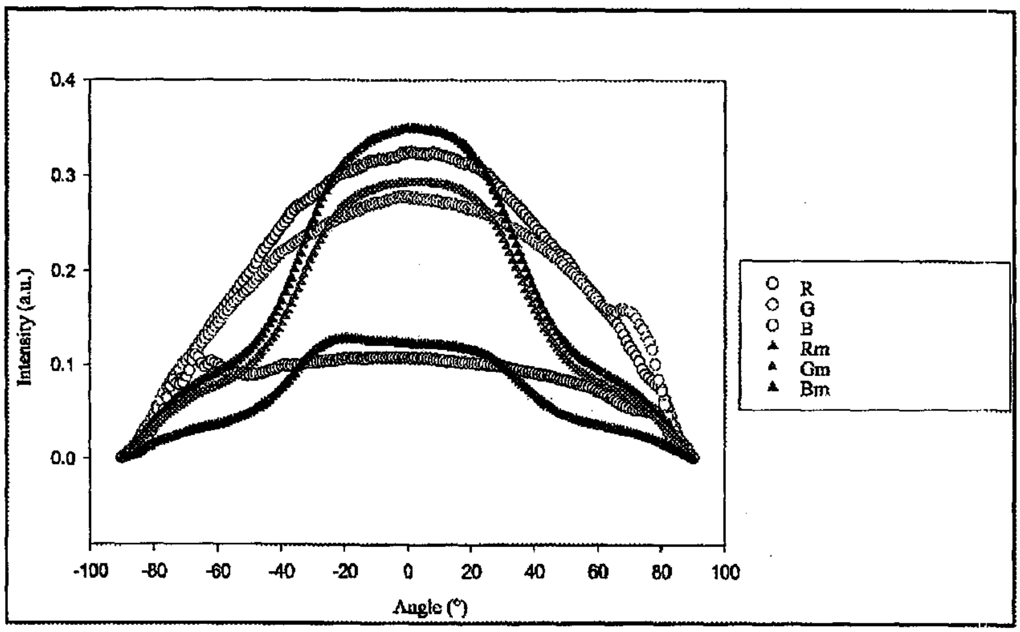
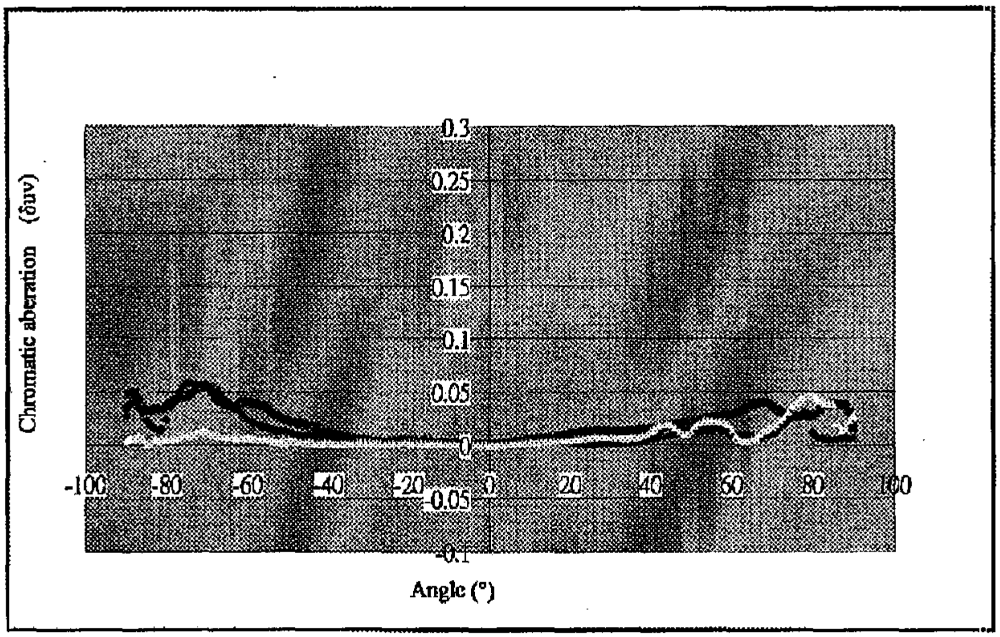
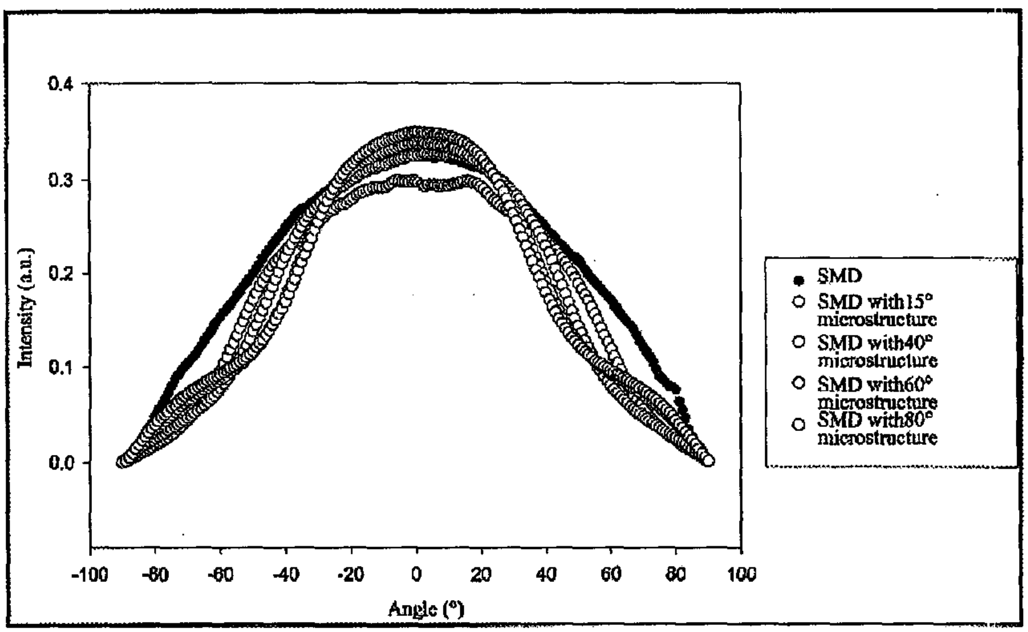

0.4
0.3
0.2
0.1
0.0
Intensity (a.u.)
-100
-80
-60
-40
-20
0
20
40
60
80
100
Angle (°)
R
G
B
Rm
Gm
Bm

FIG. 8A



Chromatic aberration (δuv)
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-100
-80
-60
-40
-20
0
20
40
60
80
100
Angle (°)

FIG. 8B



0.4
0.3
0.2
0.1
0.0
Intensity (a.u.)
-100
-80
-60
-40
-20
0
20
40
60
80
100
Angle (°)
SMD
SMD with15° microstructure
SMD with40° microstructure
SMD with60° microstructure
SMD with80° microstructure

FIG. 9A

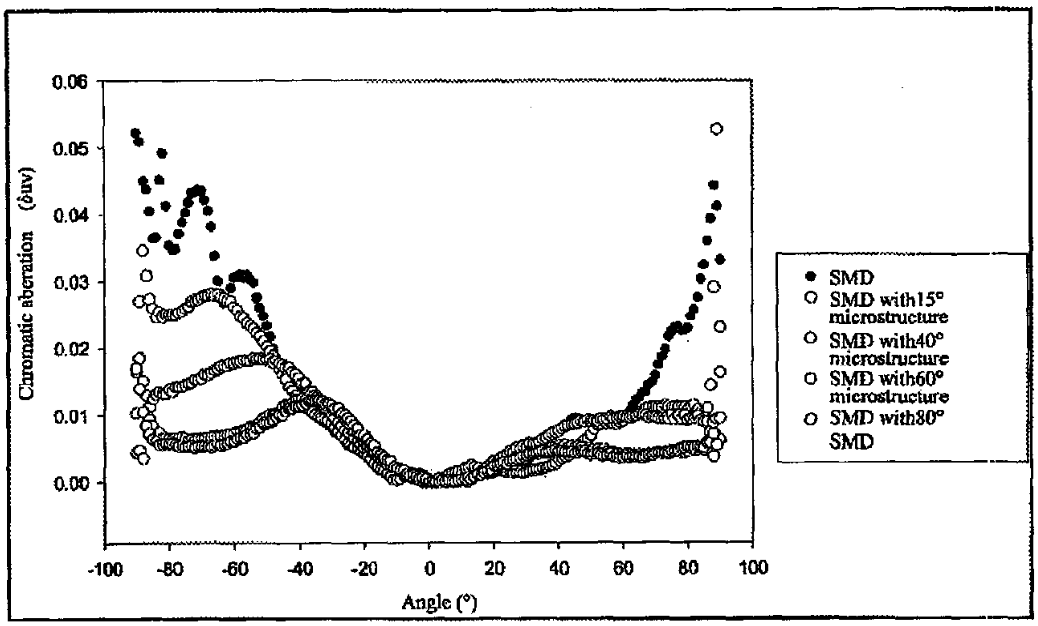

0.06
0.05
0.04
0.03
0.02
0.01
0.00
Chromatic aberration (δuv)
-100
-80
-60
-40
-20
0
20
40
60
80
100
Angle (°)
SMD
SMD with15° microstructure
SMD with40° microstructure
SMD with60° microstructure
SMD with80° SMD

FIG. 9B

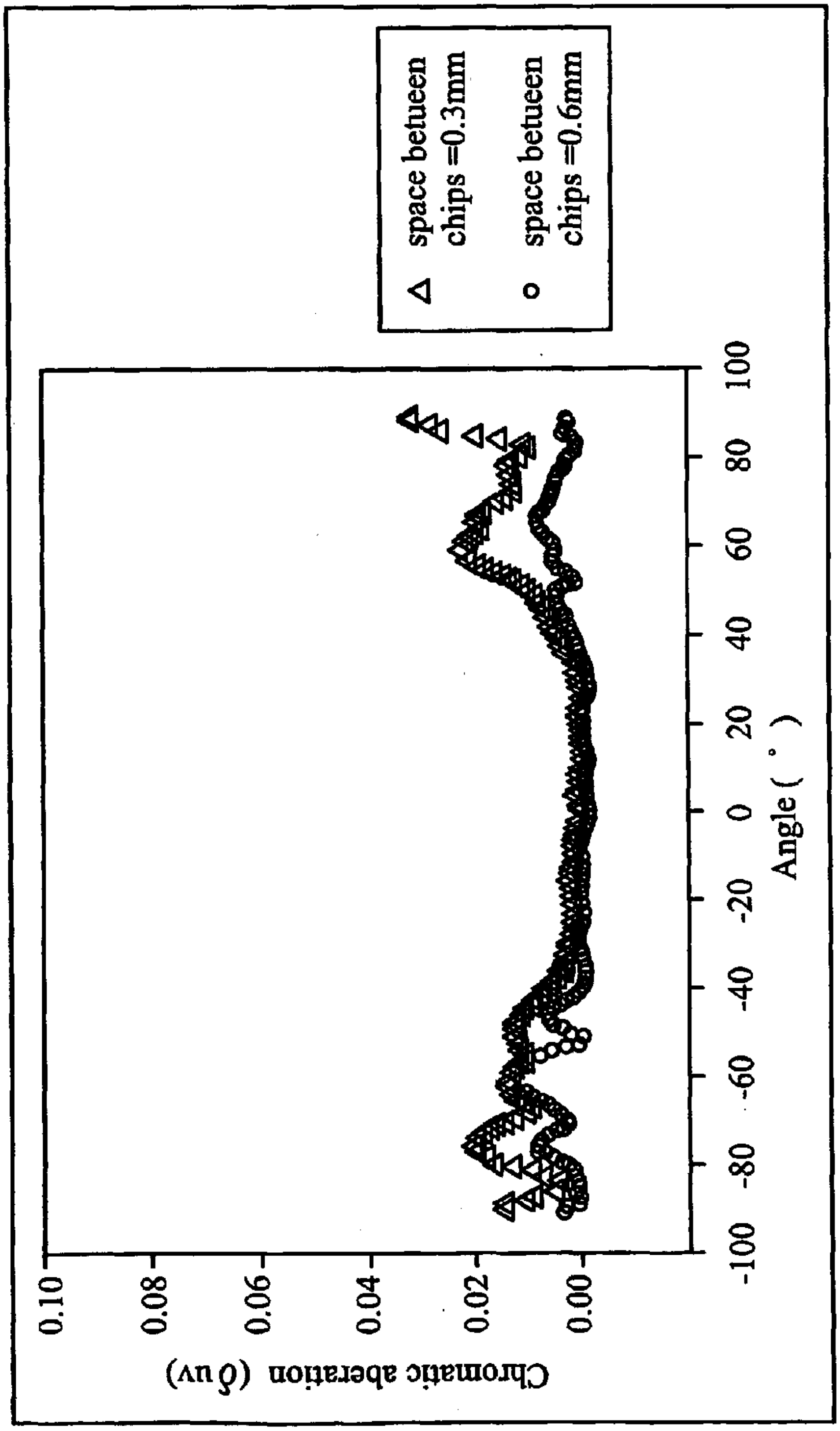

space betueen chips =0.3mm
space betueen chips =0.6mm
Chromatic aberration
0.10
0.08
0.06
0.04
0.02
0.00
-100
-80
-60
-40
-20
0
20
40
60
80
100
Angle (°)

FIG. 10

LIGHT EMITTING DIODE AND FABRICATION METHOD THEREOF

BACKGROUND

The invention relates to a light emitting diode (LED), and more particularly to a LED with molding unit and fabrication method thereof.

Multi-chip LEDs comprise a plurality of different color light emitting chips. The most common white multi-chip LED is a RGB LED. RGB LEDs comprise red (R), green (G) and blue (B) light emitting chips for obtaining white light.

FIG. 1 shows a bullet type RGB LED structure. Red light emitting chip R, green light emitting chip G and blue light emitting B are disposed in the lead frame **10**. The sidewalls of lead frame **10** comprise a highly reflective layer with a curvature for condensing the light emitted from the light emitting chips R, G and B. This type of LED further comprises lens type molding unit **12** to improve directionality thereof. A RGB LED has a good color mixing, the one would not see different color at different viewing angle. The light emitting chips R, G and B are positioned in different positions in the lead frame **10**, however, the color-mixing effect of the bullet type LED is reduced. The lens type molding unit **12** reduces the color-mixing effect.

FIG. 2 shows a surface-mount device (SMD) RGB LED structure. The SMD RGB LED has no lens type molding unit, so its directionality is worse than the bullet type RGB LED. Furthermore, the surface of the lead frame **20** of the SMD RGB LED is uneven, thus the color-mixing effect and color uniformity are improved. At the same time, the uneven surface reflects and even scatters light, both of which decrease the SMD RGB LED directionality. In short, the SMD RGB LED improves color-mixing but reduces directionality.

Thus, the bullet type LED has good directionality, but bad color-mixing; the SMD type LED has bad directionality, but good color-mixing. Hence, there is a need for a LED with good directionality and good color-mixing characteristics.

SUMMARY

Accordingly, embodiments of the invention provide a light emitting diode and fabrication method thereof.

A light emitting diode comprises a lead frame, a plurality of light emitting chips disposed in the lead frame, and a molding unit disposed in an optical path of the light emitting chips, wherein the molding unit comprises a periodic microstructure.

A light emitting diode fabrication method comprises providing a lead frame, providing a plurality of light emitting chips in the lead frame, patterning a surface of a molding unit to form a periodic microstructure, and setting the molding unit disposed in an optical path of the light emitting chips.

DESCRIPTION OF THE DRAWINGS

The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the office upon request and payment of the necessary fee.

FIG. 1 is a cross-section illustrating a conventional light emitting diode;

FIG. 2 is a cross-section illustrating another conventional light emitting diode;

FIG. 3A is a cross-section illustrating a light emitting diode of the embodiments;

FIG. 3B is a cross-section illustrating another light emitting diode of the embodiments;

FIG. 4A-4F are top-views illustrating the molding unit surface microstructure of the light emitting diode of the embodiments;

FIG. 5 is a schematic illustrating the half vertex angle of the light emitting diode;

FIG. 6A is a beam pattern illustrating the directionality of a conventional light emitting diode;

FIG. 6B is a color distribution illustrating the chromatic uniformity of a conventional light emitting diode;

FIG. 7A is a beam pattern illustrating the directionality of another conventional light emitting diode;

FIG. 7B is a color distribution illustrating the chromatic uniformity of another conventional light emitting diode;

FIG. 8A is a beam pattern illustrating the directionality of a light emitting diode of the first embodiment;

FIG. 8B is a color distribution illustrating the chromatic uniformity of a light emitting diode of the first embodiment;

FIG. 9A is a beam pattern illustrating the directionality at a different half vertex angle of a light emitting diode microstructure of the second embodiment;

FIG. 9B is a color distribution illustrating the chromatic uniformity at a different half vertex angle of a light emitting diode microstructure of the second embodiment;

FIG. 10 is a color distribution illustrating the chromatic uniformity of different light emitting chips in a given area of a light emitting diode of the third embodiment.

DETAILED DESCRIPTION

FIGS. 3A and 3B show multi-chip LEDs of the invention. The two LEDs comprise lead frame **10** (FIG. 3A) and lead frame **20** (FIG. 3B) respectively. The lead frame **10** comprises a smooth curved refrective surface to condense light. Two or more light emitting chips are disposed in the lead frame **10** and lead frame **20**. In one embodiment, there are three light emitting chips **40**, **50** and **60** in the lead frame **10** and lead frame **20** respectively. A main feature of the embodiment is the molding unit **70** with periodic microstructure **72**.

Molding unit **70** is set in the optical path of the light emitting chips **40**, **50** and **60** to condense light and mix color. The Molding unit **70** is transparent and the material thereof comprises epoxy or polymers. The polymers comprise polymethylmethacrylate (PMMA) or polycarbonate (PC). The molding unit **70** may be formed by a molding method. In this molding method, the melted epoxy or polymer mold is put in the mold, and the mold has a periodic microstructure. After solidification, the periodic microstructure of the mold is transferred to the epoxy or polymer molding unit **70** with periodic microstructure **72**. The periodic microstructure of the mold may be formed by etching, cutting tools, laser or electron beam.

The periodic microstructure **72** of the molding unit **70** is a key feature of the invention. The microstructure comprises conical protrusions (FIG. 4A) or pyramidal protrusions. The pyramidal protrusions comprise symmetric pyramidal protrusions or asymmetric pyramidal protrusions. The symmetric pyramidal protrusions comprise a base which is symmetric triangular pyramidal, square pyramidal, symmetric pentangular pyramidal or symmetric hexangular pyramidal (FIG. 4B). The asymmetric pyramidal protrusions comprise a base which is asymmetric triangular pyramidal, asymmet-

ric rectangular pyramidal (FIG. 4C), asymmetric pentangular pyramidal or asymmetric hexangular pyramidal.

The periodic microstructure **72** of the molding unit **70** also comprises flat top conical protrusions or flat top pyramidal protrusions. The flat top pyramidal protrusions comprise flat top symmetric pyramidal protrusions or flat top asymmetric pyramidal protrusions. The flat top symmetric pyramidal protrusions comprise a base which is symmetric triangular pyramidal, square pyramidal (FIG. 4E), symmetric pentangular pyramidal or symmetric hexangular pyramidal. The flat top asymmetric pyramidal protrusions comprise a base which is asymmetric triangular pyramidal, asymmetric rectangular pyramidal, asymmetric pentangular pyramidal or asymmetric hexangular pyramidal.

Furthermore, the periodic microstructure **72** of the molding unit **70** comprises round top conical protrusions (FIG. 4F) or round top pyramidal protrusions. The round top pyramidal protrusions comprise round top symmetric pyramidal protrusions or round top asymmetric pyramidal protrusions. The round top symmetric pyramidal protrusions comprise a base which is symmetric triangular pyramidal, square pyramidal, symmetric pentangular pyramidal or symmetric hexangular pyramidal. The round top asymmetric pyramidal protrusions comprise a base which is asymmetric triangular pyramidal, asymmetric rectangular pyramidal, asymmetric pentangular pyramidal or asymmetric hexangular pyramidal.

In one embodiment, the bottom size of a single microstructure is preferably smaller than the size of the light emitting chip for improving directionality and color-mixing. The single microstructure bottom size is about 20 um~1 nm, and preferably 20~200 um. The height of and single microstructure is about 20 um~1 mm, and preferably 20~200 um. In one embodiment, the space between the single microstructures is preferably smaller than its bottom size to make sure that the emitted light passing through the molding unit. The space of the single microstructure is about 20 um~1 nm, and preferably 20~200 um.

The following embodiments are white RGB LED. The 30 present invention is not only used as a RGB LED or a white LED, but also as a white multi-chip LED and other multi-chip LEDs.

The directionality and color-mixing are obtained from the following measurement and calculation.

Chromatic Light Beam Pattern Intensity and Chromatic Uniformity Calculation

First, the three-color light in different "space angles luminous intensity" of the RGB LED of the invention is measured to obtain the RGB LED beam pattern. The directionality of RGB LED is determined by the FMWH of the beam pattern. The smaller the FMWH is, the better directionality of the RGB LED is.

The RGB LED **1960** CIE UCS color coordinates in respective space angle are obtained form the beam pattern and 20 mA spectra data of the red, green and blue light emitting chips. The chromatic aberrations of RGB LED in each space angles are calculated according to beam pattern, and the chromatic aberration definition as follows:

$$\Delta uv = [(u-u_0)^2 - (v-v_0)^2]^{1/2}$$

wherein $(u-u_0)$ is the difference of the chromatic coordination at the RGB LED mechanical center, and $(v-v_0)$ is the difference of the chromatic coordination at each point of the RGB LED. A smaller chromatic aberration shows a higher chromatic uniformity of the device. In the invention, three space cross-sections 0°, 45° and 90° are analyzed to obtain the LED chromatic light space symmetry.

If the chromatic aberration is smaller than 0.008, it is difficult for the human eye to detect the color change. In practice, the color change must be unobvious (chromatic aberration <0.008) in ±30° space angle of LED.

First Comparative Embodiment

In this embodiment, the RGB LED structure is the same as FIG. **1**. The curvature radius of lens type molding unit **12** is 2.5 mm.

The chromatic light beam pattern distribution and chromatic uniformity of the RGB LED of this embodiment are shown in FIGS. **6**A and **6**B.

Second Comparative Embodiment

In this embodiment, the RGB LED structure is the same as FIG. **2**.

The chromatic light beam pattern distribution and chromatic uniformity of the RGB LED of this embodiment are shown in FIGS. **7**A and **7**B.

First Embodiment

In this embodiment, the RGB LED structure is the same as FIG. **3**B. Its microstructure **72** is conical protrusions with 46° half vertex angle (FIG. **5**).

The chromatic light beam pattern distribution and chromatic uniformity of the RGB LED of this embodiment are shown in FIGS. **8**A and **8**B.

Second Embodiment

In this embodiment, the RGB LED structures are the same as FIG. **3**B. The microstructures **72** of the RGB LEDs are conical protrusions with 15°, 40°, 60° and 80° half vertex angle (FIG. **5**).

The chromatic light beam pattern distribution and chromatic uniformity of the RGB LED of this embodiment are shown in FIGS. **9**A and **9**B.

Third Embodiment

In this embodiment, the two RGB LED structures are the same as FIG. **3**A. The microstructure **72** of the two RGB LEDs are conical protrusions with 46° half vertex angle (FIG. **5**). The distance between light emitting chips of one RGB LED is 0.3 mm, another is 0.6 mm.

The chromatic uniformity of the RGB LED of this embodiment is show in FIG. **10**.

Experiment Data and Invention Effect

1. Color-Mixing Improvement

The RGB LED of the comparative embodiment **1** is a bullet type LED, and has good directionality and bad color-mixing characteristics. After using the periodic microstructure molding unit (embodiment 1), good directionality and color-mixing characteristics can obtained at the same time:

Referring to FIGS. **6**A and **8**A, the FMWH of the comparative embodiment 1 and embodiment 1 RGB LEDs are about ±40°. In FIGS. **6**B and **8**B, the chromatic aberration of RGB LED of embodiment **1** is smaller than that of comparative embodiment **1**. Furthermore, the three cross-section space aberrations of RGB LED of embodiment **1** are more uniform. That shows the RGB LED of the embodiment **1** not only has better color-mixing but also with better space symmetry. Thus, the molding unit can improve the bullet type LED color-mixing characteristics.

2. Directionality Improvement

The RGB LED of the comparative embodiment 2 is SMD LED, and has bad directionality and good color-mixing characteristics. After using the periodic microstructure molding unit (embodiment 2), good directionality and color-mixing characteristics can be obtained at the same time:

Referring to FIG. 9B, the RGB LEDs of comparative embodiment 2 and embodiment 2 all have good color-mixing characteristics. In FIG. 9A, the FMHW RGB LEDs of the embodiment 2 are narrower than that of the comparative embodiment 2. That shows the RGB LEDs of embodiment 2 have better directionality. Thus, the molding unit can improve the SMD LED directionality characteristics.

3. Half Vertex Angle Influence

Referring to FIGS. 9A and 9B, different vertex angles can influence the directionality and color-mixing characteristics, and the influence can be predicted by optical simulation calculation.

4. Light Emitting Chips distance Influence

Referring to FIG. 10, different light emitting chip arrangements can influence the directionality and color-mixing characteristics, and the influence can be predicted by optical simulation calculation.

The foregoing description has been presented for purposes of illustration and description. Obvious modifications or variations are possible in light of the above teaching. The embodiments were chosen and described to provide the best illustration of the principles of this invention and its practical application to thereby enable those skilled in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.

What is claimed is:

1. A light emitting diode, comprising:

a lead frame;

a plurality of light emitting chips in the lead frame; and

a molding unit in an optical path of the light emitting chips, wherein the molding unit comprises a periodic microstructure, and the periodic microstructure comprises conical protrusions, asymmetric pyramidal protrusions or round top pyramidal protrusions.

2. The light emitting diode as claimed in claim 1 is a monochrome light emitting diode, a white light emitting diode or a full color light emitting diode.

3. The light emitting diode as claimed in claim 1, wherein the molding unit is transparent.

4. The light emitting diode as claimed in claim 1, wherein the asymmetric pyramidal protrusions comprise a base which is asymmetric triangular pyramidal, asymmetric rectangular pyramidal, asymmetric pentangular pyramidal or asymmetric hexangular pyramidal.

5. The light emitting diode as claimed in claim 1, wherein the conical protrusions comprises flat top conical protrusions.

6. The light emitting diode as claimed in claim 1, wherein the asymmetric pyramidal protrusions comprise flat top asymmetric pyramidal protrusions.

7. The light emitting diode as claimed in claim 6, wherein the flat top asymmetric pyramidal protrusion comprise a base which is asymmetric triangular pyramidal, asymmetric rectangular pyramidal asymmetric pentangular pyramidal or asymmetric hexangular pyramidal.

8. The light emitting diode as claimed in claim 1, wherein the conical protrusions comprises round top conical protrusions.

9. The light emitting diode as claimed in claim 1, wherein the round top pyramidal protrusions comprise round top symmetric pyramidal protrusions or round top asymmetric pyramidal protrusions.

10. The light emitting diode as claimed in claim 9, wherein the round top symmetric pyramidal protrusions comprise a base which is symmetric triangular pyramidal, square pyramidal, symmetric pentangular pyramidal or symmetric hexangular pyramidal; the round top asymmetric pyramidal protrusions comprise base which is asymmetric triangular pyramidal, asymmetric rectangular pyramidal, asymmetric pentangular pyramidal or asymmetric hexangular pyramidal.

11. The light emitting diode as claimed in claim 1, wherein the microstructure has a size of about 20 um--1 mm.

12. A light emitting diode fabrication method, comprising:

providing a lead frame;

providing a plurality of light emitting chips in the lead frame;

patterning a surface of a molding unit to form a periodic microstructure; and

setting the molding unit in an optical path of the light emitting chips,

wherein the periodic microstructure comprises conical protrusions, asymmetric pyramidal protrusions or round top pyramidal protrusions.

13. The light emitting diode fabrication method as claimed in claim 12, wherein the light emitting diode is a monochrome light emitting diode, a white light emitting diode or a full color light emitting diode.

14. The light emitting diode fabrication method as claimed in claim 12, wherein the molding unit is transparent.

15. The light emitting diode fabrication method as claimed in claim 12, wherein the patterning step comprises a molding step.

16. The light emitting diode fabrication method as claimed in claim 15, wherein the molding step employs a mold having a microstructure thereon.

17. The light emitting diode fabrication method as claimed in claim 12, wherein the asymmetric pyramidal protrusions comprise a base which is asymmetric triangular pyramidal, asymmetric rectangular pyramidal, asymmetric pentangular pyramidal or asymmetric hexangular pyramidal.

18. The light emitting diode fabrication method as claimed in claim 12, wherein the conical protrusion comprises flat top conical protrusions.

19. The light emitting diode fabrication method as claimed in claim 18, wherein the asymmetric pyramidal protrusions comprise flat top asymmetric pyramidal protrusions.

20. The light emitting diode fabrication method as claimed in claim 19, wherein the flat top asymmetric pyramidal protrusions comprise a base which is asymmetric triangular pyramidal, asymmetric rectangular pyramidal, asymmetric pentangular pyramidal or asymmetric hexangular pyramidal.

21. The light emitting diode fabrication method as claimed in claim 12, wherein the conical protrusions comprises round top conical protrusions.

sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '010 patent. The infringing instrumentalities have no substantial non-infringing uses.

73. Samsung had and continues to have actual knowledge of the '010 patent and their coverage of Samsung's infringing instrumentalities, but has nonetheless engaged in the infringing conduct. Samsung's infringement of the '010 patent was and continues to be willful.

74. As a direct and proximate result of Samsung's acts of patent infringement, ITRI has been and continues to be injured and has sustained and will continue to sustain substantial damages.

75. Unless Samsung is enjoined by this Court from continuing their infringement of the '010 patent, ITRI will suffer additional irreparable harm and impairment of the value of its patent rights.

76. ITRI has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and ITRI is entitled to recover its reasonable and necessary attorneys' fees, costs, and expenses.

X. INFRINGEMENT OF U.S. PATENT NO. 7,250,719

77. On July 31, 2007, the USPTO issued U.S. Patent No. 7,250,719, entitled "Organic Light Emitting Diode with Brightness Enhancer" (hereinafter "the '719 patent"). A true and correct copy of the '719 patent is attached hereto as Exhibit H.

78. ITRI is the owner of all right, title, and interest in and to the '719 patent by assignment, with full right to bring suit to enforce the patent, including the right to

22. The light emitting diode fabrication method as claimed in claim 12, wherein the round top pyramidal protrusions comprise round top asymmetric pyramidal protrusions or round top asymmetric pyramidal protrusions.

23. The light emitting diode fabrication method as claimed in claim 22, wherein the round top symmetric pyramidal protrusion comprise a base which is symmetric triangular pyramidal, square pyramidal, symmetric pentangular pyramidal or symmetric hexangular pyramidal; the round top asymmetric pyramidal protrusions comprise a base which is asymmetric triangular pyramidal, asymmetric

rectangular pyramidal, asymmetric pentangular pyramidal or asymmetric hexangular pyramidal.

24. The light emitting diode fabrication method as claimed in claim 12, wherein the microstructure size is smaller than the light emitting chips size.

25. The light emitting diode fabrication method as claimed in claim 12, wherein the microstructure has a size of about 20 um~1 mm.

* * * * *

EXHIBIT K

US007339716B2

(12) **United States Patent**
Ding et al.

(10) **Patent No.: US 7,339,716 B2**
(45) **Date of Patent: Mar. 4, 2008**

(54) **TRANSFLECTIVE ELECTROPHORETIC DISPLAY DEVICE**

(75) Inventors: **Jau-Min Ding**, Taipei (TW); **Chi-Chang Liao**, Tai Nan (TW); **Shie-Chang Jeng**, Ping Tung Hsien (TW); **Yi-Cheng Chen**, Hsin Chu (TW); **Chih-Chiang Lu**, Hsin Chu (TW)

(73) Assignee: **Industrial Technology Research Institute**, Hsinchu County (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 280 days.

(21) Appl. No.: **11/253,601**

(22) Filed: **Oct. 20, 2005**

(65) **Prior Publication Data**

US 2006/0087490 A1 Apr. 27, 2006

(30) **Foreign Application Priority Data**

Oct. 22, 2004 (TW) .... 93132248 A

(51) **Int. Cl.**
G02B 26/00 (2006.01)
G09G 3/34 (2006.01)

(52) **U.S. Cl.** **359/296**; 359/452; 345/107

(58) **Field of Classification Search** 359/296, 359/452, 316, 318, 320; 345/107, 105, 86, 345/60; 313/110, 495, 584–587; 349/107, 349/113

See application file for complete search history.

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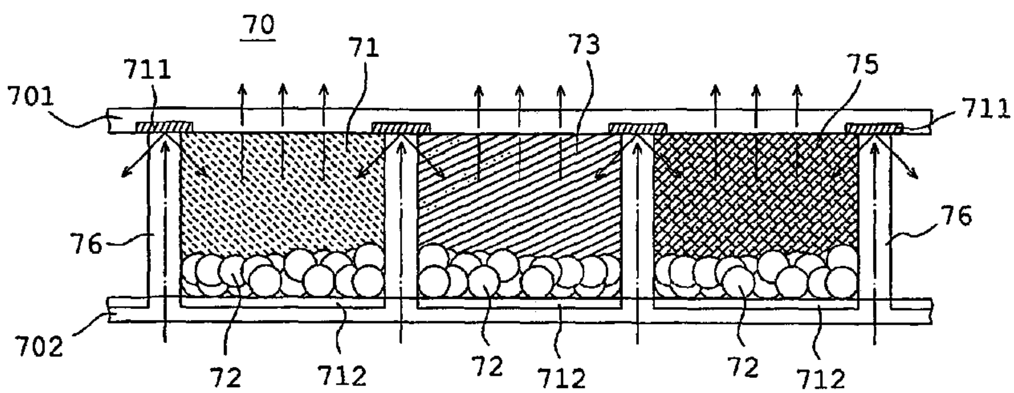
* cited by examiner

Primary Examiner—Loha Ben
(74) *Attorney, Agent, or Firm*—Rabin & Berdo, P.C.

(57) **ABSTRACT**

A transflective electrophoretic display device is disclosed. The device is comprised of a transparent top substrate and both top and bottom substrates have an electrode structure. A plurality of separated walls and an electrophoretic display solution including a plurality of chromatic particles and a transparent liquid are imposed between the two substrates. A device with a display liquid or a filter plate is used to generate a variety of lights such as monochromatic, color-level or true color having a mixture of red, green and blue. The device of the present invention integrates the merits of the reflective and transmitted displayer, and can be used outdoors, indoors or in darkness. Otherwise, a back light module can compensate for the contrast of the displayer effectively.

32 Claims, 13 Drawing Sheets



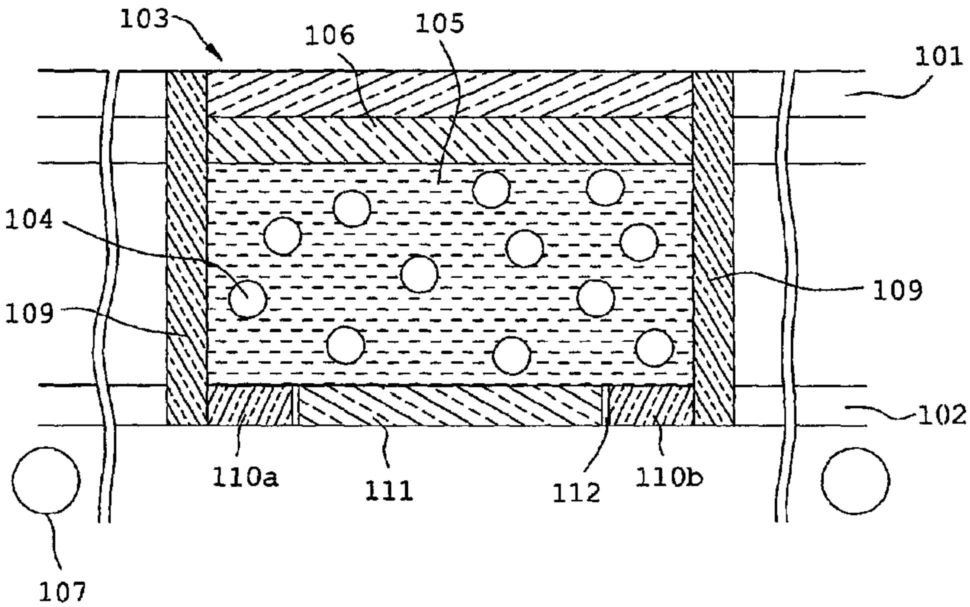


FIG. 1A
PRIOR ART

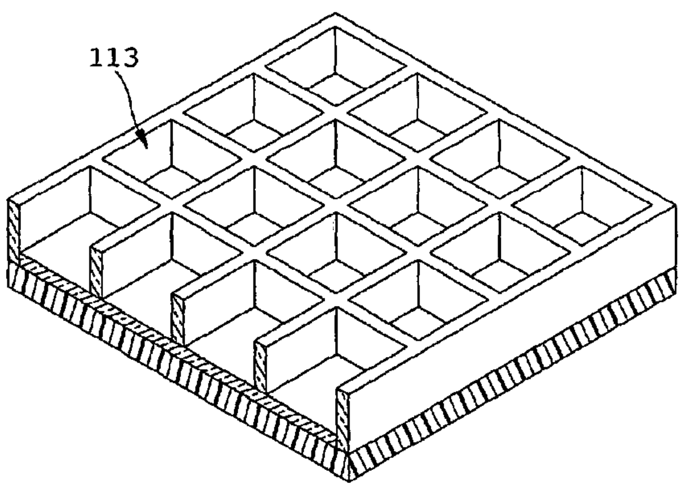


FIG. 1B
PRIOR ART

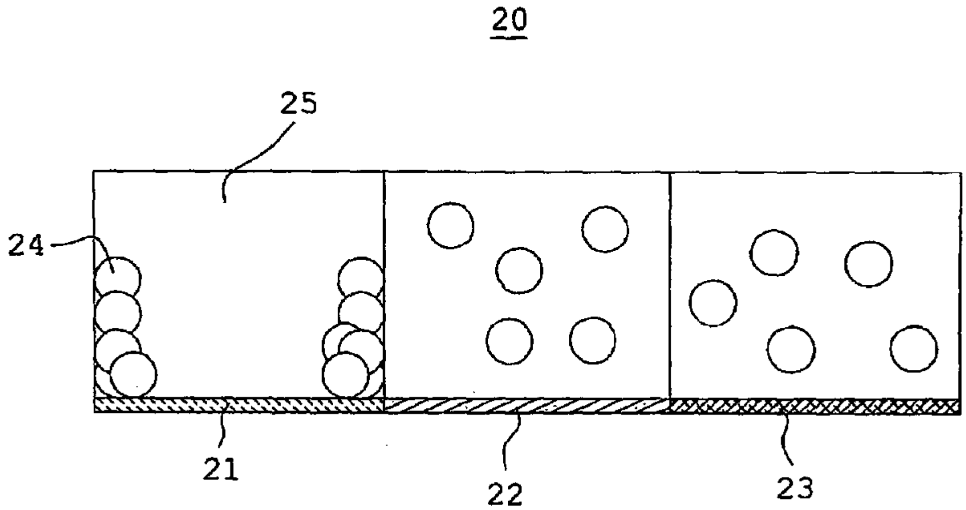


FIG.2A
PRIOR ART

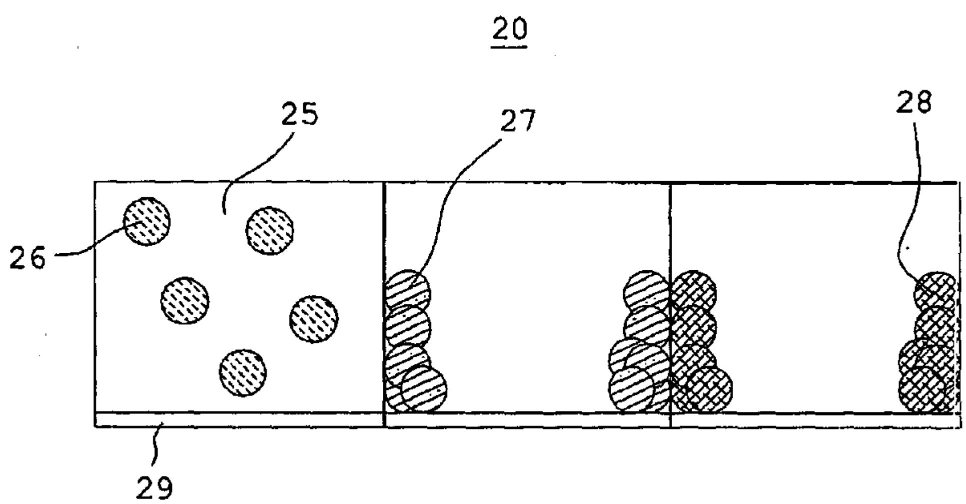


FIG.2B
PRIOR ART

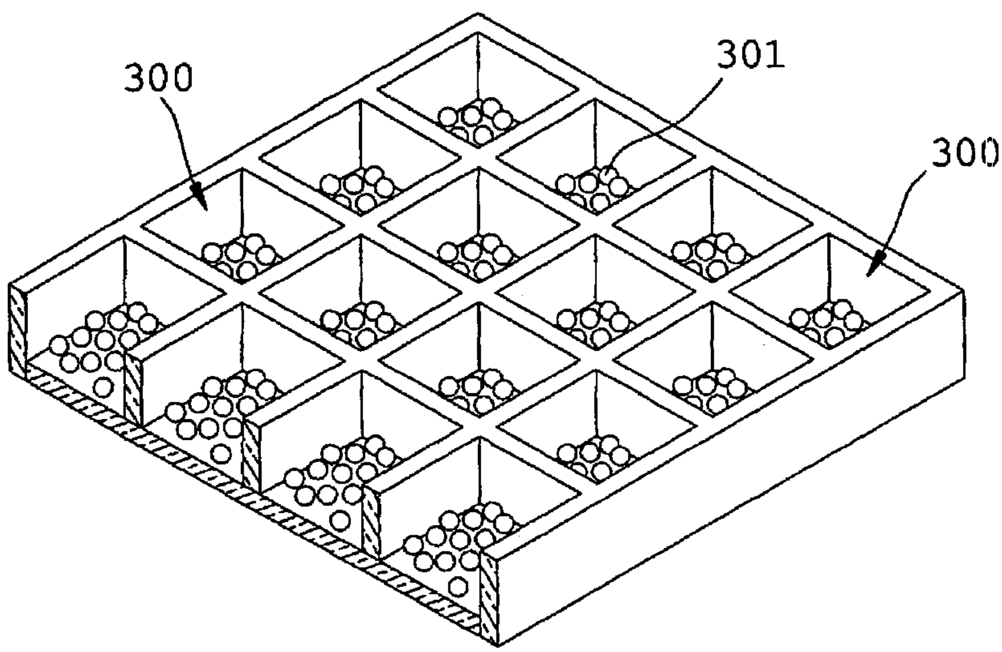


FIG. 3

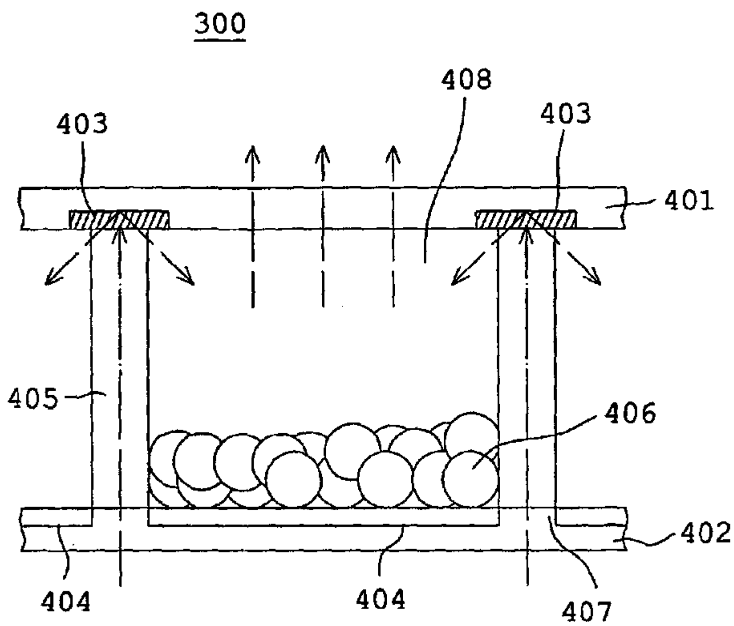


FIG. 4A

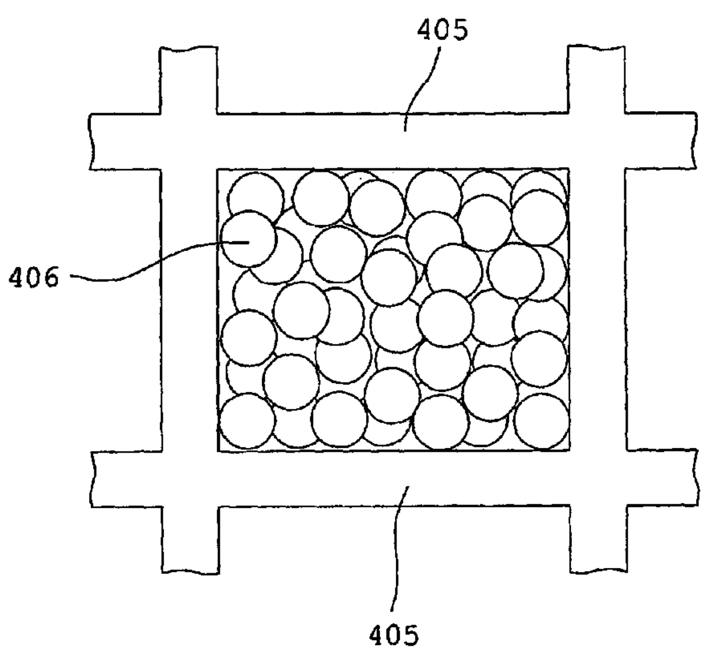


FIG. 4B

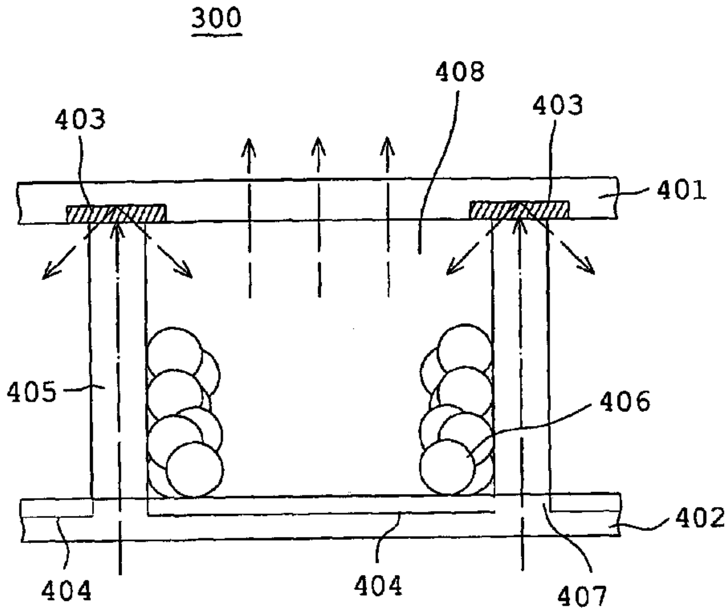


FIG.5A

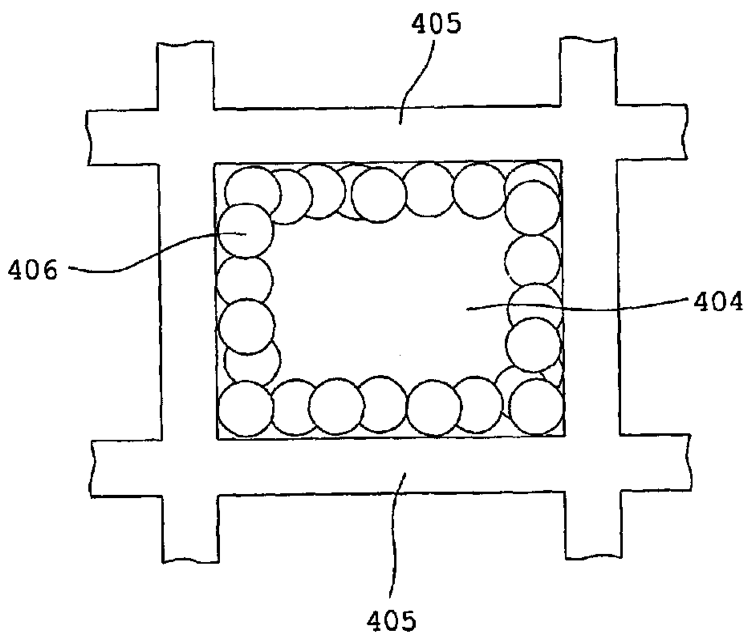


FIG.5B

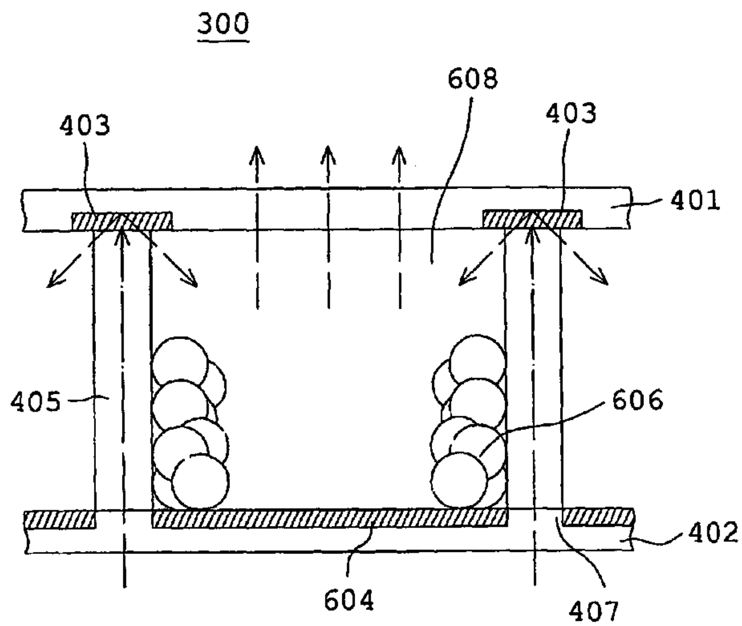

300
608
403
403
401
405
606
402
604
407

FIG. 6A

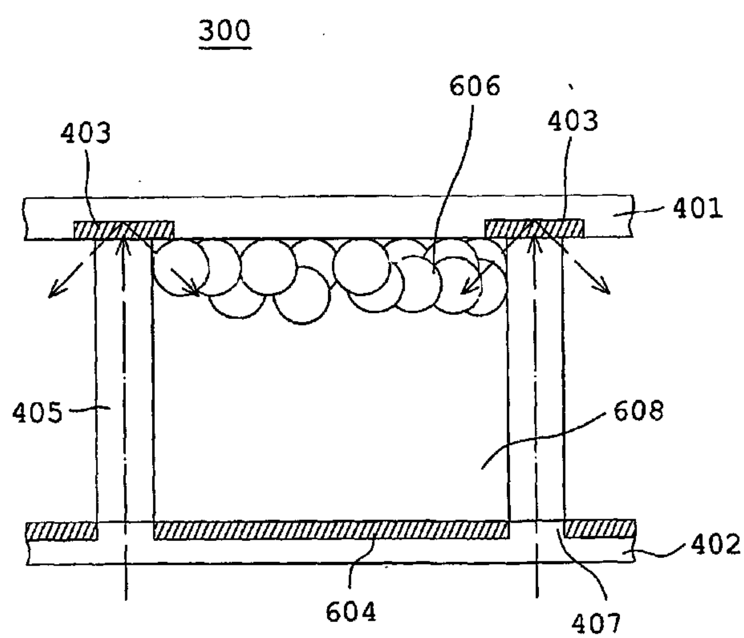

300
606
403
403
401
405
608
402
604
407

FIG. 6B

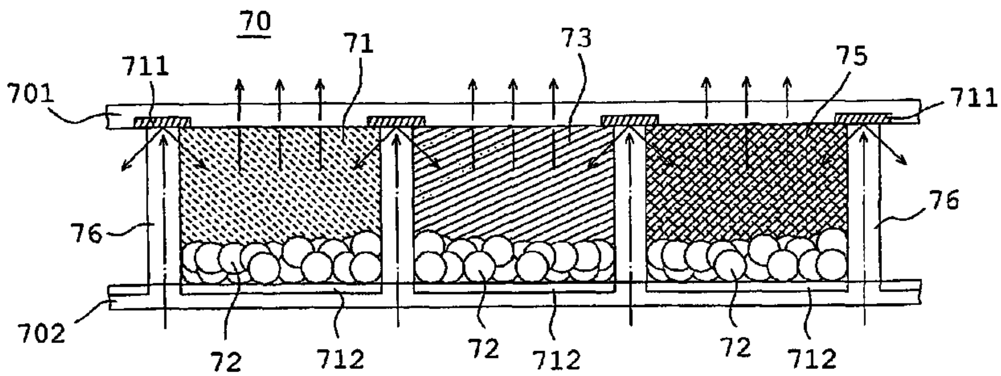


FIG. 7A

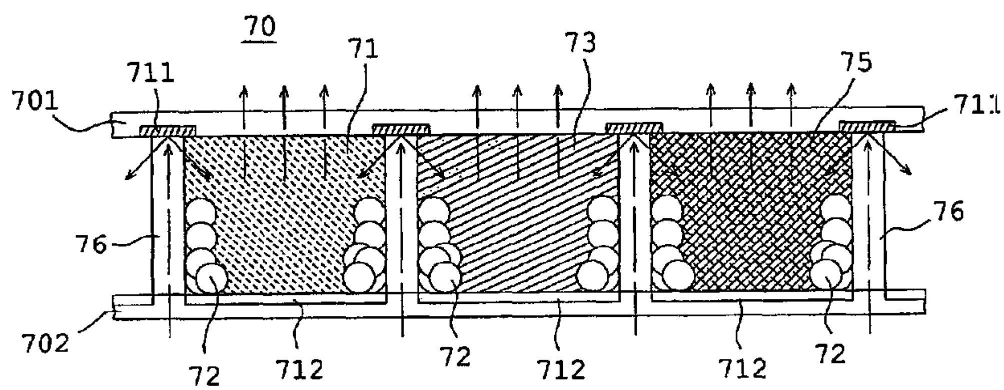


FIG. 7B

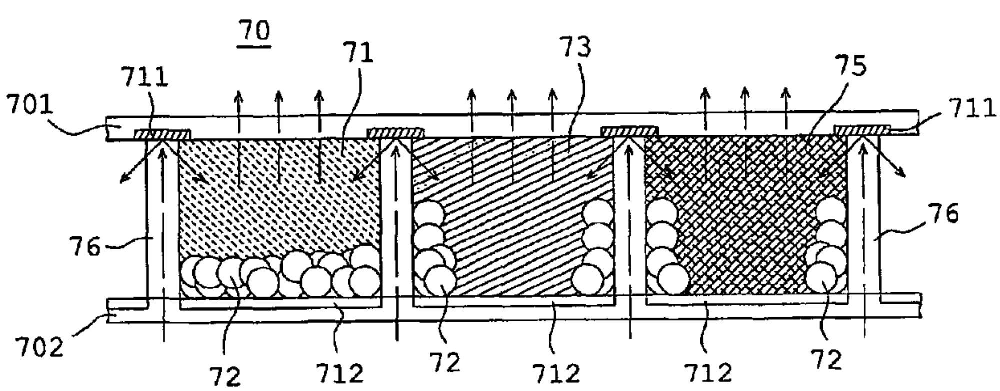


FIG. 7C

recover for past infringement damages and the right to recover future royalties, damages, and income.

79. The '719 patent is valid and enforceable.

80. All requirements under 35 U.S.C. § 287 have been satisfied with respect to the '719 patent.

81. Samsung has been and is infringing the '719 patent by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '719 patent, including but not limited to Samsung products bearing flat panel displays such as the Samsung camera TL320.

82. Samsung has been and is continuing to induce infringement of the '719 patent under 35 U.S.C. § 271(b) and contributes to the infringement of the '719 patent under 35 U.S.C. § 271(c), in conjunction with such acts of making, using, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '719 patent. The infringing instrumentalities have no substantial non-infringing uses.

83. As a direct and proximate result of Samsung's acts of patent infringement, ITRI has been and continues to be injured and has sustained and will continue to sustain substantial damages.

84. Unless Samsung is enjoined by this Court from continuing their infringement of the '719 patent, ITRI will suffer additional irreparable harm and impairment of the value of its patent rights.

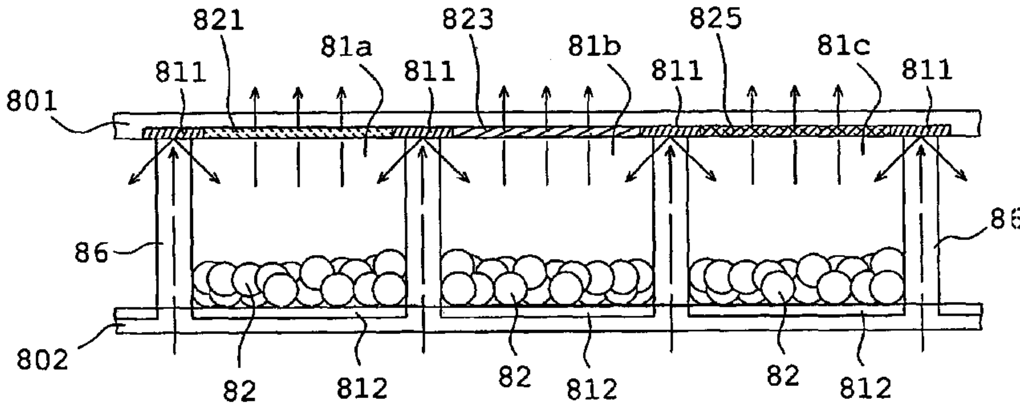

821
823
825
81a
81b
81c
811
811
811
811
801
86
86
802
82
812
82
812
82
812

FIG.8A

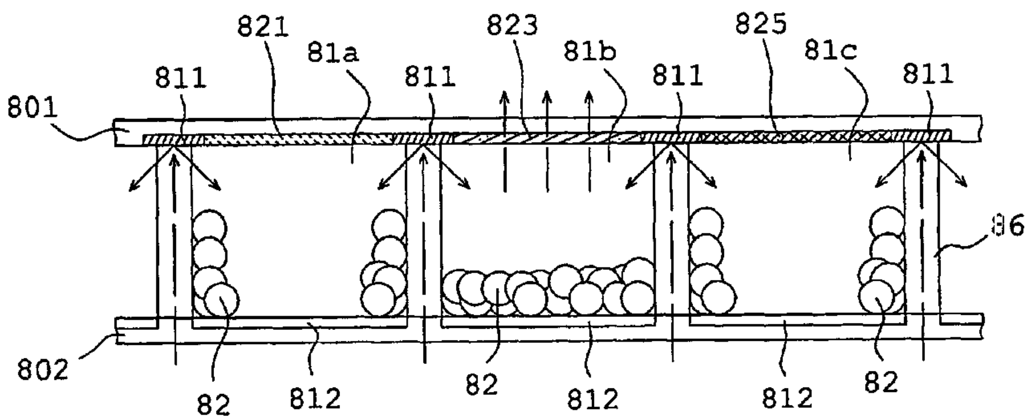

821
823
825
81a
81b
81c
811
811
811
811
801
86
802
82
812
82
812
812
82

FIG.8B

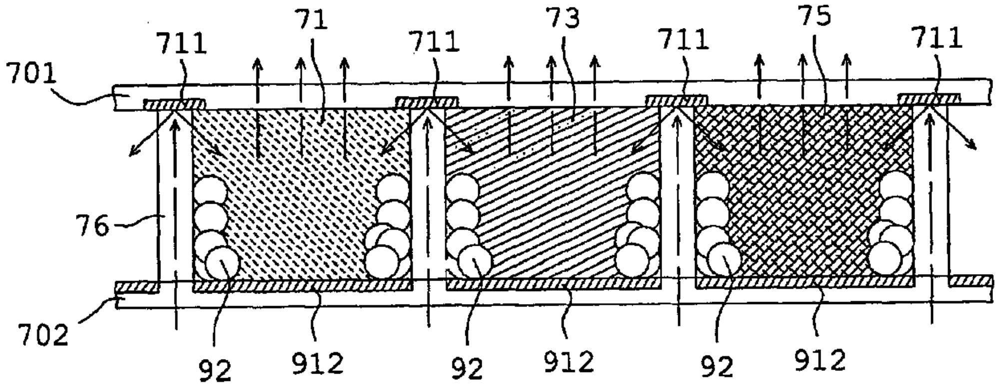

701
711
71
711
73
711
75
711
76
702
92
912
92
912
92
912

FIG. 9A

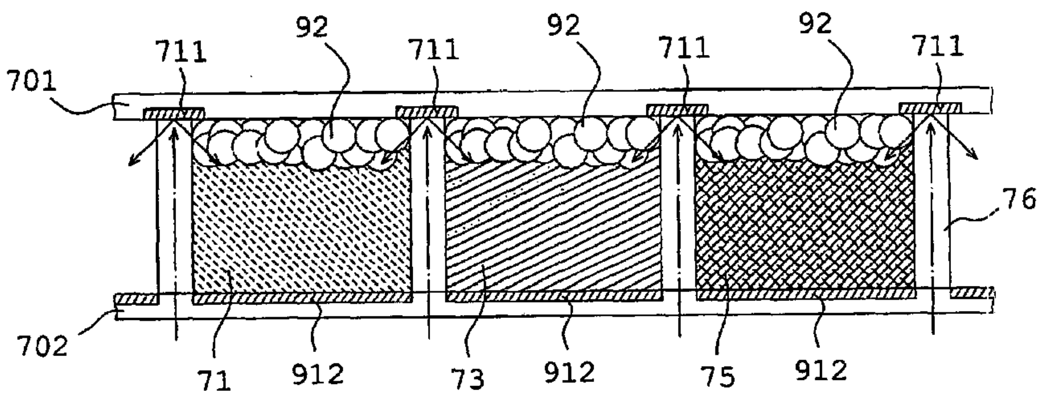

701
711
92
711
92
711
92
711
76
702
71
912
73
912
75
912

FIG. 9B

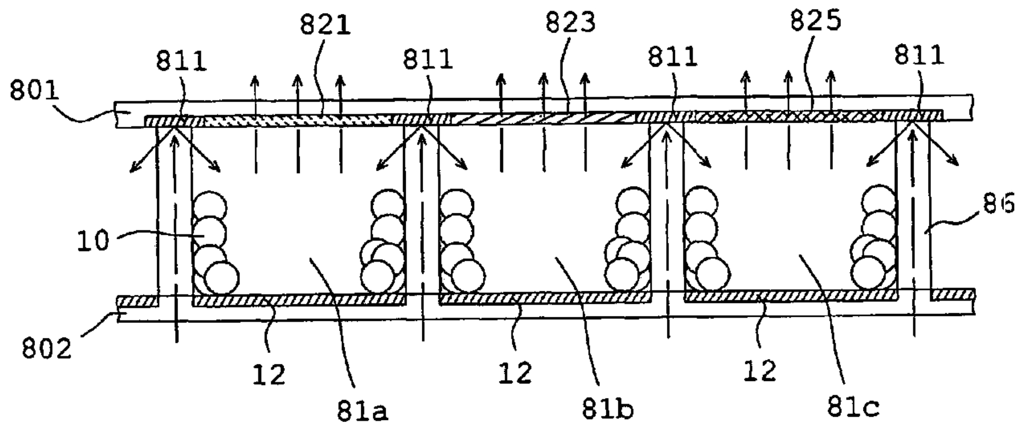


FIG.10A

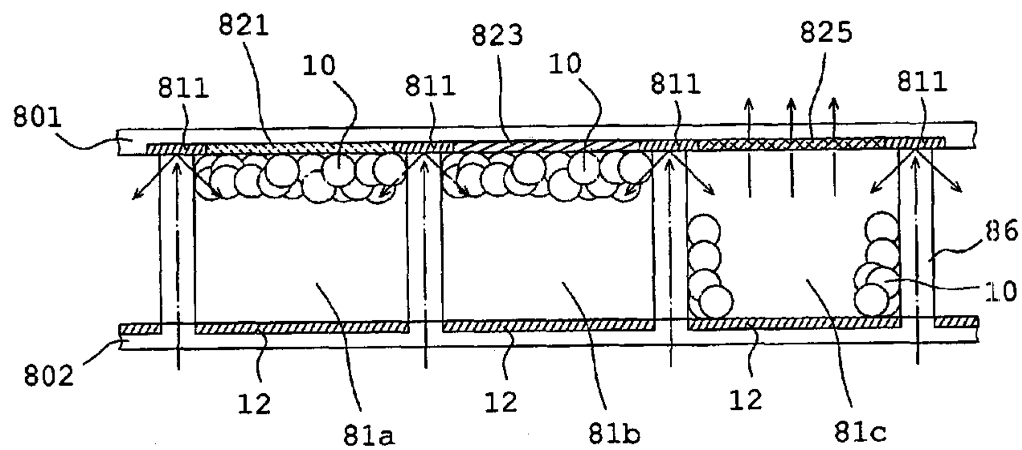


FIG.10B

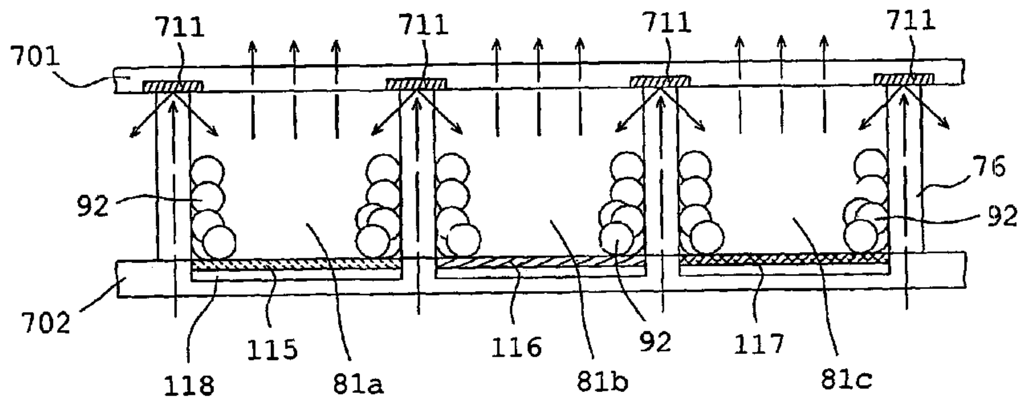


FIG.11A

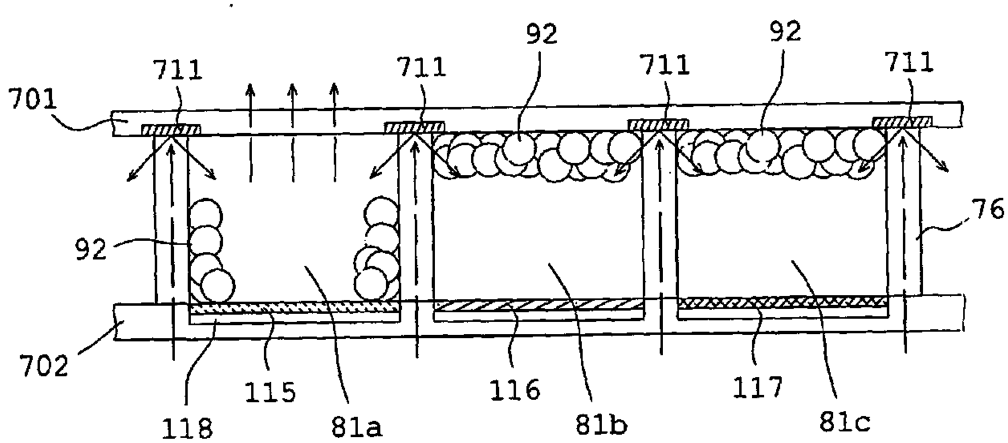


FIG.11B

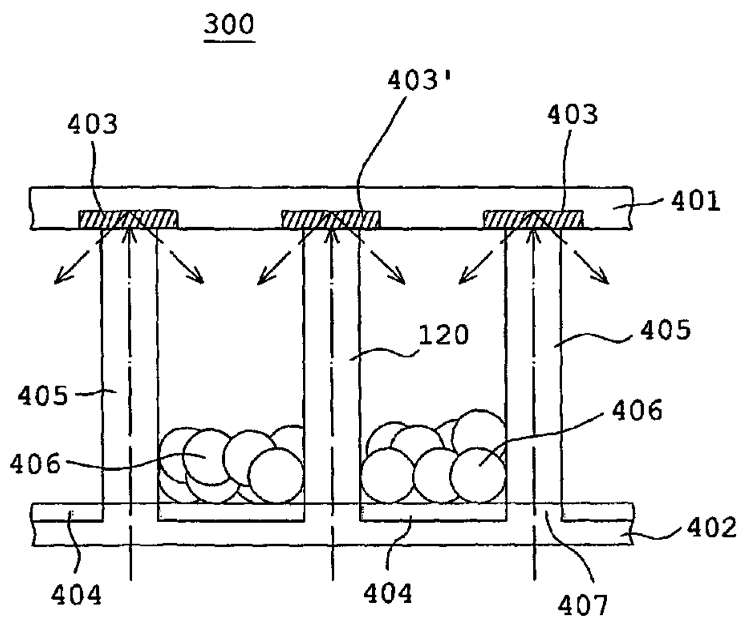


FIG.12A

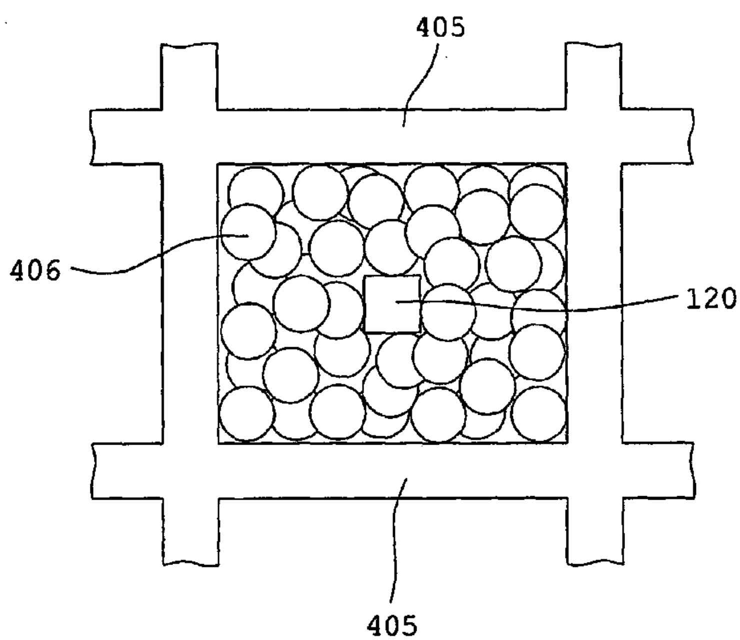


FIG.12B

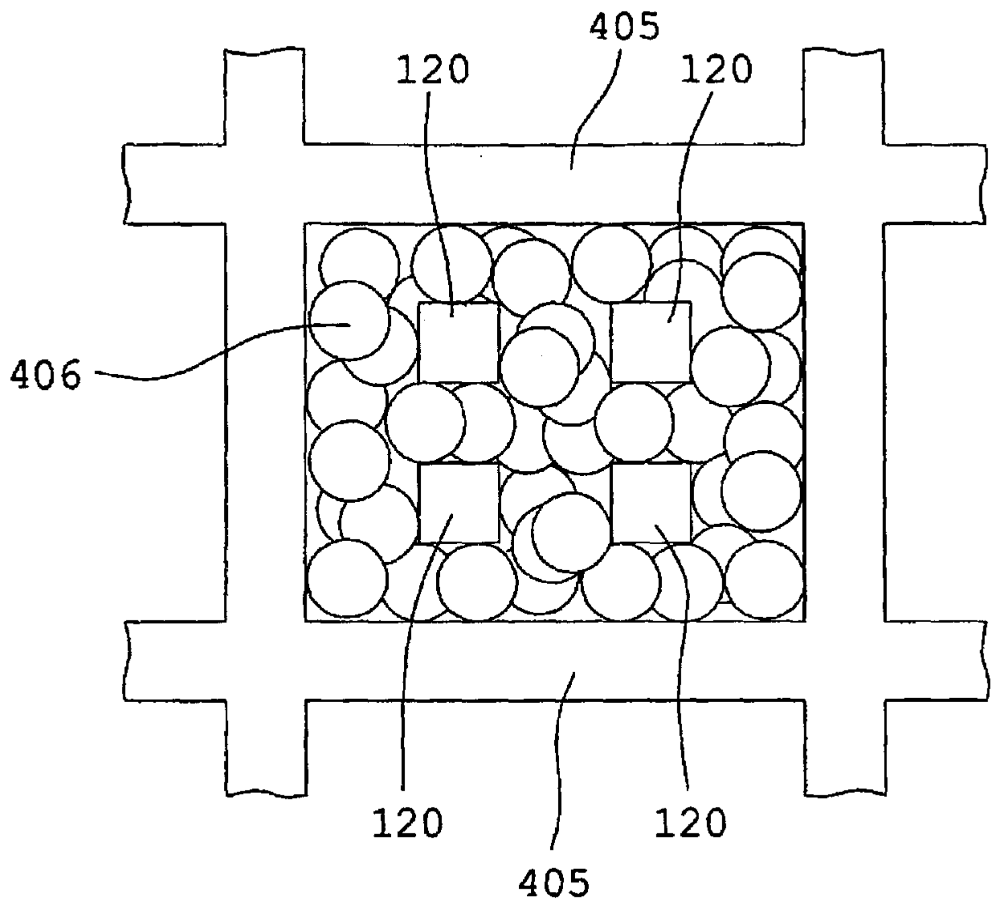


FIG. 12C

TRANSFLECTIVE ELECTROPHORETIC DISPLAY DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

A transflective electrophoretic display device is disclosed, and more particularly, a device employing a plurality of color particles affected by an electric field is introduced to display monochrome or color images.

2. Description of Related Art

A electrophoretic display device, which comprises a plurality of charged particles controlled by a provided electric field, displays by changing reflectivity in a display region therein relative to a surrounding light. The display device has the following features: (1) it's flexible; (2) it incorporates the surrounding light to improve visibility; (3) it can be manufactured by roll-to-roll process, so it has a high yield and reduces the yielding cost; (4) since there is no limit to the viewing angle, the device can be seen from any point of view; (5) it's not sensitive to the distance variation between two panels; (6) the electrophoretic display device has bistability, which is one of the most important characteristic of a flexible display device.

The surface of particles can be charged by being ionized or absorbing other charged particles. When charged particles of an electrophoretic display device are activated by an external electric field, they will move to the opposite direction relative to the electrode with opposite charges. A plurality of factors such as particle type, particle diameter, particle concentration, and the intensity, distribution and direction of the external electric field, and the type of the display solvent of the particles mentioned above will cause different moving speeds of the particles and achieve different displaying purposes.

U.S. Pat. No. 6,750,844 discloses a pliable electrophoretic display device having a deformation-resistant memory characteristic provided by covering a plurality of partitioning walls defining display sections containing a dispersion liquid with electrophoretic particles dispersed therein with an expandable ceiling sheet. U.S. Pat. No. 6,751,007 and No. 6,750,844 further disclose that the partitioning walls with high strength are disposed between the display cells. Wherein, the shape, size and the aspect ratio of the partitioning walls cause the embodiment of the display device. The plurality of pigment particles are dispersed in the solvent, and microcup technology is introduced in these prior arts. The mentioned display device with microcup structure can ignore the boundary sealing of each display cell, and accomplishes a flexible feature.

U.S. Pat. No. 6,751,007 provides a transflective electrophoretic display of SiPix Imaging, Inc. Reference is made to FIG. **1A**, which shows one of a plurality of display cells **103** divided by the partitioning walls **109**, and forms a display device. The cell **103** includes a top substrate **101**, a bottom substrate **102** with electrodes, surrounding partitioning walls, and a plurality of pigment particles **104** in the display solvent **105** filled in a space isolated by the plurality of partitioning walls **109**, and the display cell **103** is sealed by a sealing layer **106**, and finally a backlight module **107** is disposed to compensate for the displaying of the electrophoretic display device.

An electric field is generated by the electrodes in the top or bottom substrate as shown in FIG. **1A**, and an electric field is used to affect the behavior of the pigment particles **104** in the display solvent **105**. The types of the electric field include an up/down switching mode, an in-plane switching

mode and a dual switching mode. As shown in FIG. **1A**, the top substrate **101** can be a conducting glass such as Indium Tin Oxide (ITO), and the bottom substrate **102** includes in-plane electrodes **110***a* and **110***b* divided by the partitioning slabs **112** and the bottom electrode **111**.

Furthermore, U.S. Pat. No. 6,639,580 (Electrophoretic Display Device and Method for Addressing Display Device) discloses the technology of an in-plane electric field. Wherein the in-plane electrode generates an in-plane electric field to change the status of the charged particles in the display solvent and generate various display effects.

FIG. **1B** shows a display device of the prior art formed by a plurality of display cells **103** including a plurality of microcups arranged in a rectangular array. The display cell **103** of one of the embodiments includes primary colors such as red, green and blue for displaying color, namely, a three-monochromatic display cell forms a chromatic display cell.

The chromatic display cell **20** shown in FIG. **2A** includes three separated primary color sub-display cells. A plurality of white charged pigment particles **24** in the colorless display solvent **25** scatters the light emitted from the backlight module. Another embodiment shows the filtering plates **21, 22** and **23** with red, green and blue disposed in these sub-display cells.

An electric field with a different status generated by the electrodes disposed in the bottom substrate is used to guide the behavior of the charged pigment particles **24**, and further results in the scattering effect mentioned above. The primary color filtering plates **21, 22** and **23** are used to display a variety of color effects. In yet another embodiment, a further displaying result occurs if the white pigment particles **24** are changed to light-absorbed black pigment particles.

FIG. **2B** shows a chromatic display device of the prior art. The display cell **20** includes three sub-display cells with red, green and blue colors. The colorless and transparent display solvent **25** includes color pigment particles **26, 27** and **28**, which are red pigment particles **26**, green pigment particles **27** and blue pigment particles **28** respectively. The electric field is changed by the electrode in the bottom substrate with black or white plates. Those color pigment particles **26, 27** and **28** in the display solvent **25** are then activated to display various effects.

The reflective-type electrophoretic displayer of the prior art doesn't function when the surrounding light is weak or nonexistent. Moreover, the transmissive-type electrophoretic displayer is not adaptable to portable devices since it consumes a lot of power.

Some drawbacks are associated with the technology having partitioning walls in the prior art provided by the SiPix Imaging, Inc. Since the partitioning walls **109** are used as the medium for the backlight, this allows the electrophoretic displayer to operate in the dark, but the partitioning walls may possibly cause light leakage. Moreover, the backlight doesn't go through the display solvent directly, so it doesn't provide a quality of high display. Meanwhile, the electrophoretic displayer includes both the reflective-type and the transmissive-type, so it has complicated design and is difficult to fabricate.

In view of the aforementioned drawbacks of the prior art, the present invention provides a transflective electrophoretic display device, which facilitates illumination effects since both the surrounding light and the backlight can go through the display solvent completely. Meanwhile, the backlight module can be adjusted based on the condition of surrounding light, and effectively enhances the contrast of the display

and reduces power consumption. Furthermore, the present invention has a simplified design and higher manufacturing yield.

SUMMARY OF THE INVENTION

A transflective electrophoretic display device is provided for illuminating with or without surrounding light. A light emitted from a backlight module can be adjusted according to the condition of the surrounding light so as to reduce power consumption and enhance the quality of the display.

The transflective electrophoretic display device is composed of a plurality of display cells, the display device comprises a top substrate, which is a transparent substrate having a plurality of anisotropic reflective plates; a bottom substrate having a plurality of light plates and a plurality of electrodes so as to generate an electric field, and the bottom substrate is installed opposite to the top substrate; a plurality of partitioning walls, which are transparent materials are disposed between the top substrate and the bottom substrate so as to isolate the plurality of display cells; a display solution, which is composed of a plurality of pigment particles and transparent liquid to fill a space isolated by the top substrate, the bottom substrate and the partitioning walls. Wherein, the electric field in the display cell is changed to guide the behavior of the plurality of charged pigment particles in the display solution, a light emits to the anisotropic reflective plates of the top substrate through the partitioning walls, and the plates reflect the light to the display solution so as to radiate monochromatic or gray-scale effects.

The transflective electrophoretic display device is composed of a plurality of display cells, and each display cell is further composed of a plurality of sub-display cells having red, green and blue colors. The display device comprises a top substrate, which is a transparent substrate having a plurality of anisotropic reflective plates; a bottom substrate having a plurality of light plates and a plurality of electrodes so as to generate an electric field, and the bottom substrate is installed opposite to the top substrate; a plurality of partitioning walls, which are transparent materials and disposed between the top substrate and the bottom substrate so as to isolate the plurality of sub-display cells; a red display solution, a green display solution and a blue display solution which are composed of a plurality of pigment particles and transparent liquids so as to fill a space isolated by the top substrate, the bottom substrate and the partitioning walls. Wherein, the electric field in the display cell is changed to guide the behavior of the plurality of charged pigment particles in the red, green, and blue display solution, a light emits to the anisotropic reflective plates of the top substrate through the partitioning walls, and the reflective plates reflect the light to the red, green and blue display solution so as to radiate color effects.

Furthermore, the transflective electrophoretic display device of another embodiment is composed of a plurality of display cells, and the display cell is further composed of a plurality of sub-display cells having a red filter, a green filter and a blue filter with a transparent material installed on the top substrate or the bottom substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be readily understood by the following detailed description in conjunction with the accompanying drawings, in which:

FIG. 1A is a schematic diagram of a display cell of a transflective electrophoretic display of the prior art;

FIG. 1B is a schematic diagram of a transflective electrophoretic display of the prior art;

FIG. 2A is a schematic diagram of the color display device of the prior art;

FIG. 2B is a schematic diagram of the color display device of the prior art;

FIG. 3 is a schematic diagram of a transflective electrophoretic display device of the present invention;

FIG. 4A is a lateral view of the first embodiment of the present invention in a WHITE-state;

FIG. 4B is an overlooking viewing view of the first embodiment of the present invention in a WHITE-state;

FIG. 5A is a lateral view of the first embodiment of the present invention in a BLACK-state;

FIG. 5B is an overlooking view of the first embodiment of the present invention in a BLACK-state;

FIG. 6A is a lateral view of the second embodiment of the present invention in a WHITE-state;

FIG. 6B is a lateral view of the second embodiment of the present invention in a BLACK-state;

FIG. 7A is a lateral view of the third embodiment of the present invention in a WHITE-state;

FIG. 7B is a lateral view of the third embodiment of the present invention in a BLACK-state;

FIG. 7C is a lateral view of the third embodiment of the present invention in a RED-state;

FIG. 8A is a lateral view of the fourth embodiment of the present invention in a WHITE-state;

FIG. 8B is a lateral view of the fourth embodiment of the present invention in a GREEN-state;

FIG. 9A is a lateral view of the fifth embodiment of the present invention in a WHITE-state;

FIG. 9B is a lateral view of the fifth embodiment of the present invention in a BLACK-state;

FIG. 10A is a lateral view of the sixth embodiment of the present invention in a WHITE-state;

FIG. 10B is a lateral view of the sixth embodiment of the present invention in a GREEN-state;

FIG. 11A is a lateral view of the seventh embodiment of the present invention in a WHITE-state;

FIG. 11B is a lateral view of the seventh embodiment of the present invention in a RED-state;

FIG. 12A is a lateral view of the eighth embodiment of the transflective electrophoretic display device of the present invention;

FIG. 12B is an overlooking view of the eighth embodiment of the transflective electrophoretic display device of the present invention; and

FIG. 12C is an overlooking view of the eighth embodiment of the transflective electrophoretic display device of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

To allow the examiner to understand the technology, means and functions adopted in the present invention further, reference is made to the following detailed description and attached drawings. The examiner shall readily understand the invention deeply and concretely from the purpose, characteristics and specification of the present invention. Nevertheless, the present invention is not limited to the attached drawings and embodiments in following description.

A transflective electrophoretic display device of the present invention is introduced to integrate the advantages of the conventional reflective and transmissive electrophoretic displayer. The display device includes a transparent top substrate, and a top/bottom substrate having in-plane electrodes. A plurality of partitioning walls and a display solution having a plurality of pigment particles and a transparent liquid are disposed between the two substrates so as to generate monochromatic, or color-scale, or color effects. The display device of the present invention facilitates brightness since both the surrounding light and the backlight can go through the mentioned display solution completely. Moreover, the brightness of the backlight can be adjusted based on the condition of the surrounding light, and effectively enhance the contrast of the display and reduce the power consumption.

FIG. 3 is a schematic diagram of a transflective electrophoretic display device composed of a plurality of display cells **300**, which form a rectangular array, and other embodiments such as a hexagon, a circular form, a rhombus or the like, but not limited to these. The display device of the present invention can be implemented as a flexible device because of the microcup structure therein. The display cell **300** is isolated by the top substrate, the bottom substrate and the plurality of partitioning walls; a space therebetween can be filled with a transparent liquid having a plurality of pigment particles **301**. Wherein, the pigment particles **301** can be white, black, chromatic, or other transparent chromatic particles. An electric field generated in virtue of the electrodes in the substrates can be changed to change the dispersed behavior of the charged particles so as to change the displaying effect.

FIG. 4A and FIG. 4B show the first embodiment of the present invention in a white state. The display cell **300** includes a top substrate **401** with a transparent material, a bottom substrate **402** having an electrode structure installed on the other side of the top substrate **401**, and a space isolated by the partitioning walls **405**. A plurality of anisotropic reflective plates **403** are installed along the top substrate **401** relative to the positions of the partitioning walls **405**. The electrodes with in-plane switching mode are disposed in the bottom substrate **402** or even the top substrate **401** so as to generate an in-plane electric field. A black absorbing plate **404** of the preferred embodiment is installed along the bottom substrate **402** excluding the area where the partitioning walls **405** contact the bottom substrate. The aforementioned partitioning walls **405** are transparent, and a light source (not shown in this diagram) is set below the display cell **300**. A backlight from the light source is emitted to the anisotropic reflective plates **403** of the top substrate **401** from a gap **407** of the absorbing plate and through the partitioning walls **405**. The incidental light is reflected to the space of the cell, but not the original direction from the light source due to the anisotropic reflective plates **403**. Additionally, the surrounding light also enters the display solution **408** and fills the space identical to the backlight so as to enhance the displaying effect efficiently.

The mentioned electrophoretic display solution **408** includes the charged white particles **406** and the transparent liquid of the preferred embodiment. The features of the display solution, such as its color and transparency, are used to generate various displaying modes, or even collocate the features, such as color, transparency and reflectivity, of the bottom substrate.

Nevertheless, the area of the anisotropic reflective plates of the top substrate is larger or equal to the area occupied by the partitioning walls. In this embodiment, the area of the

anisotropic reflective plates occupy 1% to 99% of the total area of the display device, but 7% to 60% is preferred to produce better displaying effects. The open area of the space of the display cell is 10^2 to 10^6 μm^2, but the preferred area is 10^3 to 10^5 μm^2. The distance between the top substrate and the bottom substrate is 5 to 200 μm, but the preferred distance is 10 to 100 μm.

The first embodiment in white-state is shown in FIG. 4A. The dash line shows the light path of the backlight emitted through the gap **407** from a backlight module below the bottom substrate **402** to the anisotropic reflective plates **403** of the top substrate **401** via the partitioning walls **405**. The backlight is reflected by the anisotropic reflective plates **403** to the display solution **408** of the cell, and the display cell displays a white state since the charged white particles **406** reflects or scatters the light out. The light source can also be surrounding light emitting to the display cell **300** through the top substrate **401**, and reflected or scattered by the white particles **406** so as to display a white state. In another embodiment, the color of pigment particles can be changed to another color or become transparent so as to radiate the various colors of the display device.

FIG. 4B shows an overlooking view of the display device in a white state. Each display cell **300** thereof is isolated by the partitioning walls **405** between the top and bottom substrates. The white particles **406** with reflective features are dispersed on the bottom substrate **402**, the white particles **406** reflect the incidental light out to form white light.

FIG. 5A is a lateral view of the first embodiment of the present invention in the black state. The backlight emits through the gap **407** of the absorbing plate **404** to the top substrate **401** via the transparent partitioning walls **405**. The anisotropic reflective plates **403** reflect the light to the display solution **408** of the display cell **300**. The white particles **406** are dispersed leaning against the partitioning walls **405** due to the effect of the electric field. Since the bottom of the display cell **300** is the black absorbing plate **404**, the reflected light is absorbed by the plate **404** so as to radiate in a black state. Similarly, the surrounding light enters the display solution **408** directly and becomes absorbed by the black absorbing plate **404** so as to radiate in a black state. If the anisotropic reflective plates **403** are chromatic plates in this embodiment, the display device **300** can display various effects.

Reference is made to FIG. 5B, which shows an overlooking view of the first embodiment in a black state. The white particles **406** are dispersed leaning against the partitioning walls **405** due to the action of the electric field. The absorbing plate **404** of the bottom substrate **402** absorbs the incidental light so as to radiate in a black state.

The structure of the display cell of the second embodiment shown in FIG. 6A is similar to the structure in FIG. 4A. Wherein a space of the display cell is isolated by the partitioning walls **405** between the top substrate **401** and the bottom substrate **402**. The space is filled with a display solution **608** having a plurality of black particles **606** and a transparent liquid. The plurality of anisotropic reflective plates **403** is disposed along the top substrate **401** excluding the area where the partitioning walls **405** contact the top substrate **401**. The electrodes can be installed on the top or bottom substrate, and thereby the electric field is generated accordingly. The absorbing or reflective plates, such as the reflective plate **604** shown in the diagram, are disposed along the bottom substrate **402** excluding the area where the partitioning walls **405** contact the bottom substrate **402**. A light source set below the display cell emits through the gap **407** of the reflective plate **604** and goes through the parti-

tioning walls **405**. The anisotropic reflective plates **403** of the top substrate **401** reflect the light to the display solution **608** so as to radiate in a white state since the reflective plate **604** reflects the incidental light.

The charged black particles **606** are dispersed leaning against the partitioning walls **405** according to the action of the electrodes in the top substrate **401** or the bottom substrate **402**. The incidental light is reflected or scattered by the reflective plate **604** of the bottom substrate **402** so as to radiate in a white state. The color of the reflective plate **604** of another embodiment can be changed to display various effects.

FIG. **6B** shows the second embodiment of the present invention in a black state. The black particles **606** thereof are dispersed to the top substrate **401** according to the action of the electric field generated by the electrodes in the top or the bottom substrate. After that, the black particles **606** block the light reflected or scattered by the reflective plate **604** of the bottom substrate **402**. They also block the incidental surrounding light so as to radiate in a black state. Wherein, the display cell **300** shows different colors since the black particles **606** can be changed to other color particles.

The structure of the mentioned display cell includes the top substrate **401** having electrodes therein and the anisotropic reflective plates **403** are disposed along the area where the partitioning walls **405** contact the top substrate **401**. The display cell further includes the bottom substrate **402** having lateral electrodes and the reflective plate **403** therein. The display cell composed of the top substrate **401** and the bottom substrate **402** is a micro-structure, and the display solution **408** that fills the isolated space inside contains the plurality of black particles **606** and the transparent liquid.

The electric field generated by the electrodes in the bottom substrate **402** can be an in-plane switching mode. The electric field generated by the electrodes disposed in both the top substrate **401** and the bottom substrate **402** can be an up/down switching mode, an in-plane switching mode, or a dual switching mode. A backlight module is further disposed below the bottom substrate **402**.

The present invention also provides a display cell for displaying color effects. The display cell therein at least includes three sub-display cells with the three primary colors, and each cell is composed of a transparent top substrate, the top/bottom substrate having in-plane electrodes, the plurality of partitioning walls therebetween and the display solution having the plurality of charged pigment particles and the transparent liquid with three different colors or three color filters. Both the surrounding light and the backlight can go through the display solution completely so as to enhance the displaying effect. The backlight can be adjusted so that it appears to be brighter or darker based on the condition of the surrounding light. Thereby, the present invention can efficiently reduce power consumption and enhance the contrast and tint.

FIGS. 7A, 7B and 7C are the lateral view of the third embodiment of the present invention. The color display cell **70** includes the top substrate **701** with a transparent material, the bottom substrate **702** with electrodes disposed along the bottom substrate **702** opposite to the top substrate **701**, a micro-structure space isolated by the partitioning walls **76**. The color display cell **70** displays color effects using the sub-display cells having the three primary colors, red, green and blue. Otherwise, the electrodes disposed in the top substrate **701** and the bottom substrate **702** can generate an up/down switching mode, an in-plane switching mode or the a dual switching mode.

An absorbing or reflecting plate, such as the black absorbing plate of this embodiment, is installed along the bottom substrate **702** excluding the area where the partitioning walls **76** contact the bottom substrate **702**. The partitioning walls **76** thereof are transparent, and the light source is disposed below the color display cell **70**. The light shown as the dash line in the diagram emits from the light source through the gap of the absorbing plate **712**, and enters the partitioning walls **76**, then hits the anisotropic reflective plate **711** of the top substrate **701**. The light is finally reflected by the anisotropic reflective plate **711** and enters the space of the color display cell **70**. The aforementioned light can completely pass through the display solutions **71**, **73** and **75**, and the surrounding light can also enter the display cell **70** so as to radiate light efficiently.

Further, the color display cell **70** includes a transparent liquid such as a red display solution **71**, a green display solution **73** and a blue display solution **75**. Therein, the liquid contains charged pigment particles **72** including the white particles that can reflect or scatter light broadly. The light reflected by the anisotropic reflective plate **711** can radiate different color effects through the color display solution.

FIG. 7A shows the third embodiment in the white state of the present invention. Wherein, the dash line presents the path of light, which emits from the backlight module below the bottom substrate **702** through the gap of the absorbing plate **712** thereof. After that, the light enters the partitioning walls **76**, and is reflected by the anisotropic reflective plates **711** disposed on the top substrate **701**. Then the reflected light goes into the spaces filled with the red, green and blue display solutions **71**, **73** and **75** respectively. In the meantime, since the charged pigment particles **72** in the display solutions **71**, **73** and **75** controlled by the electric field are dispersed on the bottom substrate **702**, the incidental light reflected by the anisotropic reflective plates **711** is reflected or scattered by the white particles **72**. Afterwards, the light reflected or scattered from each color solution radiates and is mixed into an even white light of this embodiment. Otherwise, both the backlight and the surrounding light pass through the display solutions **71**, **73** and **75** completely and are reflected or scattered so as to become an efficient display cell.

FIG. 7B is a lateral view of the third embodiment of the present invention in a black state. The color display cell **70** includes at least three primary color sub-display cells. The light emits through the gap of the absorbing plate **712** of the bottom substrate **702**, and enters the transparent partitioning walls **76**. Then the light hits the top substrate **701**, and the anisotropic reflective plates **711** thereof reflect the incidental light to the spaces filled with the display solutions **71**, **73** and **75** respectively. In this embodiment, since the white particles **72** are dispersed leaning against the partitioning walls **76**, the bottom of the space shows the black absorbing plate **712**, which absorbs the incidental light so as to radiate in the black state of the color display cell **70**.

FIG. 7C shows the red state of the third embodiment. The pigment particles **72** in the green display solution **73** and the blue display solution **75** are dispersed leaning against the partitioning walls **76** due to the action of the electric field, then the bottom substrate **702** allows the black absorbing plate **712** to be seen yet doesn't reflect or scatter any chromatic light. However, the pigment particles **72** in the red display solution **71** are dispersed on the bottom substrate **702** so as to reflect the incidental light reflected by the

85. ITRI has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and ITRI is entitled to recover its reasonable and necessary attorneys' fees, costs, and expenses.

XI. INFRINGEMENT OF U.S. PATENT NO. 7,270,457

86. On September 18, 2007, the USPTO issued U.S. Patent No. 7,270,457, entitled "Light Source Device and Projector Using the Same" (hereinafter "the '457 patent"). A true and correct copy of the '457 patent is attached hereto as Exhibit I.

87. ITRI is the owner of all right, title, and interest in and to the '457 patent by assignment, with full right to bring suit to enforce the patent, including the right to recover for past infringement damages and the right to recover future royalties, damages, and income.

88. The '457 patent is valid and enforceable.

89. All requirements under 35 U.S.C. § 287 have been satisfied with respect to the '457 patent.

90. Samsung has been and is infringing the '457 patent by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '457 patent, including but not limited to Samsung video projectors.

91. Samsung has been and is continuing to induce infringement of the '457 patent under 35 U.S.C. § 271(b) and contributes to the infringement of the '457 patent under 35 U.S.C. § 271(c), in conjunction with such acts of making, using, offering for sale, and/or importing in or into the United States, without authority, products that fall

anisotropic reflective plates **11**. The reflected light passes through the red display solution **71** so as to radiate in a red state.

The aforementioned embodiments show the color display cell **72** can display a variety of states since the pigment particles **72** thereof vary based on the action of the electric field.

FIG. **8**A is a lateral view of the fourth embodiment of the present invention in a white state. These micro-structure spaces of the display cell isolated by the partitioning walls **86** between the top substrate **801** and the bottom substrate **802** are filled with transparent display solutions **81***a*, **81***b* and **81***c* having a plurality of white and reflective pigment particles **82**. The anisotropic reflective plates **811** are disposed along the top substrate **801** relative to the position of the partitioning walls **86**. Furthermore, red, green and blue filters **821**, **823** and **825** with transparent material are disposed along the bottom substrate **802** relative to the position of the micro-structure space. The white state of the display cell is created by mixing the primary colors for each sub-display cell. The light emits from the backlight module installed on the one side of the bottom substrate **802** to the anisotropic reflective plates **811** of the top substrate **801** through the partitioning walls **86**. Then the reflected light goes through the display solutions **81***a*, **81***b* and **81***c* of the sub-display cells. Meanwhile, the charged pigment particles **82** therein are dispersed upon the substrate **802** due to the action of the electric field. After that, the incidental light reflects and passes through the red filter **821**, the green filter **823** and the blue filter **825**, finally forming white light. The surrounding light can be incorporated as the light source of the present embodiment; both the backlight and the surrounding light are used to enhance the displaying efficiency.

FIG. 8B shows the green state of the display cell having the red filter **821**, the green filter **823** and the blue filter **825** on the top substrate **801**. The pigment particles **82** are changed due to the action of the electric field. The various states of the pigment particles **82** cause various displaying effects because of the mixture of the primary colors. As shown in the diagram, the pigment particles **82** in the display solutions **81***a* and **81***c* are dispersed leaning against the partitioning walls **86** due to the action of the electric field. When the light hits the black absorbing plates **812** on the bottom substrate **802** through the display solutions **81***a* and **81***c*, no red or blue light is reflected from these sub-display cells. But the pigment particles **82** in the display solution **81***b* are dispersed upon the bottom substrate **802**. Finally, the incidental light reflected or scattered by the pigment particles **82** passes through the green filter **823** so as to radiate green light.

If the white particles are changed to pigment particles with absorbing material, the white state of the display cell will be shown as the fifth embodiment of the present invention. The micro-structure spaces filled with the red display solution **71**, the green display solution **73** and the blue display solution **75** respectively are isolated by the partitioning walls **76** between the top substrate **701** and the bottom substrate **702**. Bottom reflective plates **912** are disposed along the bottom substrate **702** relative to the position of the display solutions **71**, **73** and **75**. The aforementioned bottom reflective plate **912** can be a scattering-type reflective plate. The pigment particles **92** with absorbing material are dispersed leaning against the partitioning walls **76** due to the action of the electric field. After that, the light reflected by the anisotropic reflective plates **711** is reflected by the bottom reflective plates **912** and passes through the display solutions **71**, **73** and **75** with red, green and blue colors so as to radiate in a white state.

Reference is made to FIG. 9B, which shows the fifth embodiment of the present invention in a black state. The charged pigment particles **92** are dispersed upon the top substrate **701**, so the light reflected by the bottom reflective plates **912** is blocked by the pigment particles **92** so as to display a black state. The states of the pigment particles can be changed to display various effects based on the action of the electric field.

FIG. **10**A is a lateral view of the sixth embodiment of the present invention in a white state. The micro-structure spaces are filled with the transparent display solutions **81***a*, **81***b* and **81***c*. Wherein, a color display cell of the present embodiment includes red, green and blue sub-display cells having the plurality of pigment particles with absorbing material. The charged pigment particles **12** vary according to the action of the electric field. The pigment particles **10** are dispersed leaning against the partitioning walls **86** of the embodiment, and the light is reflected or scattered by the bottom reflective plates **12** as it passes through the filters **821**, **823** and **825** and displays white light by mixing the primary colors.

FIG. **10**B is a lateral view of the sixth embodiment of the present invention in a green state. The pigment particles **10** in the display solutions **81***a*, **81***b* are dispersed upon the top substrate **801**, and used to block the light reflected or scattered by the bottom reflective plates **12**, so the reflected or scattered light won't pass through the red filter **821** and the green filter **823**. Nevertheless, the pigment particles **10** in the display solution **81***c* are dispersed leaning against the partitioning walls **86**, so the light reflected or scattered by the bottom reflective plate 12 will pass through the blue filter **825** so as to radiate in a blue state.

FIG. **11**A and FIG. **11**B show the seventh embodiment of the present invention. The red filter **115**, the green filter **116**, the blue filter **117** and the bottom reflective plates **118** are disposed on the bottom substrate **702** of the sub-display cells. The light reflected or scattered by the bottom reflective plate **118** goes through the red, green and blue filters so as to show various colors. The bottom reflective plates **118** of the other embodiments can be the respective primary colors reflective plates for each sub-display cell. The light reflected or scattered by the mentioned bottom reflective plates can be used to show various effects. Otherwise, the light source can be a backlight, a surrounding light, or both.

FIG. **11**A shows the white state of this embodiment. The pigment particles **92** in the display solutions **81***a*, **81***b* and **81***c* are dispersed leaning against the partitioning walls **76**. The light reflected or scattered by the bottom reflective plates **118** passes through each filter **115**, **116** and **117** respectively, and radiates white light by mixing the primary colors evenly.

FIG. **11**B shows the red state of the display device. The pigment particles **92** are dispersed to block the reflected or scattered light in the display solutions **81***b* and **81***c*, so that no light is emitted. But the pigment particles **92** with absorbing material in the display solution **81***a* are dispersed leaning against the partitioning walls **76**, so the light reflected or scattered by the bottom reflective plate **118** passes through the red filter **115** so as to finally display a red state.

Furthermore, one or a plurality of light guides is installed in the aforementioned space isolated by the partitioning walls in the display device. Reference is made to FIG. **12**A, which is a lateral view of the eighth embodiment of the transflective electrophoretic display device. The light from

the backlight module emits to the anisotropic reflective plates **403** of the top substrate **401** through the partitioning walls **405**, and is reflected to the display solution thereof. However, a light guide **120** connected with the top substrate **401** and the bottom substrate **402** is installed in the space. The backlight can be emitted to the top substrate **401** through the light guide **120**. After that, the light is reflected to the display solution by the anisotropic reflective plate **403'** disposed at a position relative to the light guides. Whereby, the light guide can enhance the brightness of the transflective electrophoretic display device and facilitate the displaying effect.

FIG. **12B** is an overlooking view of the display device with the light guide **120**. FIG. **12C** is the overlooking view of the display device with a plurality of light guides **120** disposed between the top substrate and the bottom substrate of the present invention.

The invention may be embodied in other specific forms without departing from the sprit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed is:

1. A transflective electrophoretic display device, which is composed of a plurality of display cells, the display device comprises:

a top substrate, which is a transparent substrate having a plurality of anisotropic reflective plates of the display device;

a bottom substrate having a plurality of light plates and a plurality of electrodes so as to generate an electric field, and the bottom substrate is installed opposite to the top substrate;

a plurality of partitioning walls, which are transparent materials and disposed between the top substrate and the bottom substrate so as to isolate the plurality of display cells;

a display solution, which is composed of a plurality of pigment particles and transparent liquid so as to fill a space isolated by the top substrate, the bottom substrate and the partitioning walls;

wherein the electric field in the display cell is changed to guide the behavior of the plurality of charged pigment particles in the display solution, a light emits to the anisotropic reflective plates of the top substrate through the partitioning walls, and the plates reflect the light to the display solution so as to radiate monochromatic or gray-scale effects.

2. The transflective electrophoretic display device as recited in claim **1**, wherein a light source is disposed below the display device.

3. The transflective electrophoretic display device as recited in claim **1**, wherein the anisotropic reflective plates of the top substrate are disposed relative to the partitioning walls.

4. The transflective electrophoretic display device as recited in claim **1**, wherein the light plates are reflective plates or absorbing plates.

5. The transflective electrophoretic display device as recited in claim **1**, wherein the light plates are chromatic reflective plates.

6. The transflective electrophoretic display device as recited in claim **1**, wherein the plurality of pigment particles are white particles, black particles, chromatic particles or chromatic transparent particles.

7. The transflective electrophoretic display device as recited in claim **1**, wherein the electrodes of the bottom substrate are a plurality of side electrodes.

8. The transflective electrophoretic display device as recited in claim **1**, wherein the electrodes of the bottom substrate generate an in-plane electric field.

9. The transflective electrophoretic display device as recited in claim **1**, wherein the electrodes of the bottom substrate and a plurality of electrodes of the top substrate generate an up/down switching mode, an in-plane switching mode or a dual switching mode electric field.

10. The transflective electrophoretic display device as recited in claim **1**, wherein one or a plurality of light guides connected with the top substrate and the bottom substrate is disposed in the space isolated by the top substrate, the bottom substrate and the partitioning walls.

11. A transflective electrophoretic display device, the display device is composed of a plurality of display cells, and the display cells are further composed of a plurality of sub-display cells having red, green and blue colors, the display device comprises:

a top substrate, which is a transparent substrate having a plurality of anisotropic reflective plates of the display device;

a bottom substrate having a plurality of light plates and a plurality of electrodes so as to generate an electric field, and the bottom substrate is installed opposite to the top substrate;

a plurality of partitioning walls, which are transparent materials and disposed between the top substrate and the bottom substrate so as to isolate the plurality of sub-display cells;

a red display solution, which is composed of a plurality of pigment particles and transparent liquid so as to fill a space isolated by the top substrate, the bottom substrate and the partitioning walls;

a green display solution, which is composed of a plurality of pigment particles and transparent liquid so as to fill a space isolated by the top substrate, the bottom substrate and the partitioning walls;

a blue display solution, which is composed of a plurality of pigment particles and transparent liquid so as to fill a space isolated by the top substrate, the bottom substrate and the partitioning walls;

wherein the electric field in the display cell is changed to guide the behavior of the plurality of charged pigment particles in the red, green and blue display solutions, a light emits to the anisotropic reflective plates of the top substrate through the partitioning walls, and the reflective plates reflect the light to the red, green and blue display solutions so as to radiate color effects.

12. The transflective electrophoretic display device as recited in claim **11**, wherein a backlight module is disposed below the display device.

13. The transflective electrophoretic display device as recited in claim **11**, wherein the anisotropic reflective plates of the top substrate are disposed relative to the partitioning walls.

14. The transflective electrophoretic display device as recited in claim **11**, wherein the light plates are reflective plates or absorbing plates.

15. The transflective electrophoretic display device as recited in claim **11**, wherein the light plates are scattering-type reflective plates.

16. The transflective electrophoretic display device as recited in claim 11, wherein the plurality of pigment particles are reflective white particles or absorbent black particles.

17. The transflective electrophoretic display device as recited in claim 11, wherein the electrodes of the bottom substrate are a plurality of side electrodes.

18. The transflective electrophoretic display device as recited in claim 11, wherein the electrodes of the bottom substrate generate an in-plane electric field.

19. The transflective electrophoretic display device as recited in claim 11, wherein the electrodes of the bottom substrate and a plurality of electrodes of the top substrate generate an up/down switching mode, an in-plane switching mode or a dual switching mode electric field.

20. The transflective electrophoretic display device as recited in claim 11, wherein one or a plurality of light guides connecting with the top substrate and the bottom substrate is disposed in the space isolated by the top substrate, the bottom substrate and the partitioning walls.

21. A transflective electrophoretic display device, the display device is composed of a plurality of display cells, and the display cells are further composed of a plurality of sub-display cells having red, green and blue colors, the display device comprises:

a top substrate, which is a transparent substrate having a plurality of anisotropic reflective plates of the display device;

a bottom substrate having a plurality of light plates and a plurality of electrodes so as to generate an electric field, and the bottom substrate is installed opposite to the top substrate;

a plurality of partitioning walls, which are transparent materials and disposed between the top substrate and the bottom substrate so as to isolate the plurality of sub-display cells;

a plurality of display solutions, which are composed of a plurality of pigment particles and transparent liquids, the display solutions fill a space isolated by the top substrate, the bottom substrate and the plurality of partitioning walls of the sub-display cells of the display cells;

a red filter, which is a transparent material installed on the top substrate or the bottom substrate;

a green filter, which is a transparent material installed on the top substrate or the bottom substrate;

a blue filter, which is a transparent material installed on the top substrate or the bottom substrate;

wherein the electric field in the display cell is changed to guide the behavior of the plurality of charged pigment particles in each display solution, a light emits to the anisotropic reflective plates of the top substrate through the partitioning walls, and the reflective plates reflect the light to the display solution and through the red, green and blue filters so as to radiate various effects.

22. The transflective electrophoretic display device as recited in claim 21, wherein a backlight module is disposed below the display device.

23. The transflective electrophoretic display device as recited in claim 21, wherein the anisotropic reflective plates of the top substrate are disposed relative to the partitioning walls.

24. The transflective electrophoretic display device as recited in claim 21, wherein the red, green and blue filters of the top substrate are disposed relative to the space.

25. The transflective electrophoretic display device as recited in claim 21, wherein the red, green and blue filters of the bottom substrate are disposed relative to the space.

26. The transflective electrophoretic display device as recited in claim 21, wherein the light plates are reflective plates or absorbent plates.

27. The transflective electrophoretic display device as recited in claim 21, wherein the light plates are scattering-type reflective plates.

28. The transflective electrophoretic display device as recited in claim 21, wherein the plurality of pigment particles are reflective white particles or absorbent black particles.

29. The transflective electrophoretic display device as recited in claim 21, wherein the electrodes of the bottom substrate are a plurality of side electrodes.

30. The transflective electrophoretic display device as recited in claim 21, wherein the electrodes of the bottom substrate generate an in-plane electric field.

31. The transflective electrophoretic display device as recited in claim 21, wherein the electrodes of the bottom substrate and a plurality of electrodes of the top substrate generate an up/down switching mode, an in-plane switching mode or a dual switching mode electric field.

32. The transflective electrophoretic display device as recited in claim 21, wherein one or a plurality of light guides connecting with the top substrate and the bottom substrate is disposed in the space isolated by the top substrate, the bottom substrate and the partitioning walls.

* * * * *

EXHIBIT L

US007387858B2

(12) **United States Patent**
Chari et al.

(10) **Patent No.:** **US 7,387,858 B2**
(45) **Date of Patent:** **Jun. 17, 2008**

(54) **REFLECTIVE DISPLAY BASED ON LIQUID CRYSTAL MATERIALS**

(75) Inventors: **Krishnan Chari**, Fairport, NY (US); **John C. Kowalczyk**, Denver, CO (US); **Charles M. Rankin, Jr.**, Penfield, NY (US); **Erica N. Montbach**, Pittsford, NY (US)

(73) Assignee: **Industrial Technology Research Institute**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 236 days.

(21) Appl. No.: **11/216,628**

(22) Filed: **Aug. 31, 2005**

(65) **Prior Publication Data**

US 2006/0134349 A1 Jun. 22, 2006

Related U.S. Application Data

(63) Continuation-in-part of application No. 11/017,181, filed on Dec. 20, 2004, now abandoned.

(51) **Int. Cl.**
C09K 19/00 (2006.01)
C09K 19/52 (2006.01)

(52) **U.S. Cl.** **430/20**; 428/1.1; 428/1.2; 252/299.01; 349/176

(58) **Field of Classification Search** 428/1.1, 428/1.2; 430/20; 252/299.01; 349/176
See application file for complete search history.

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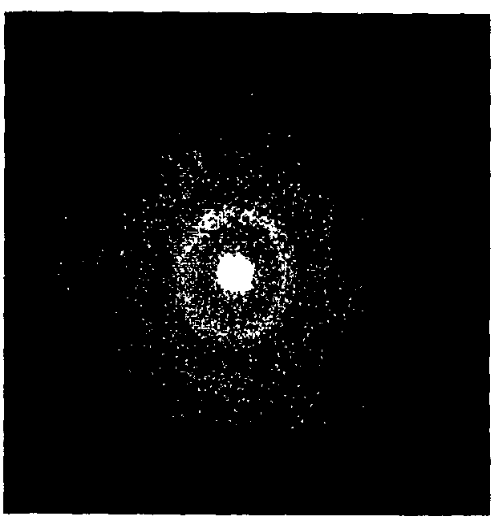
Primary Examiner—Geraldina Visconti
(74) *Attorney, Agent, or Firm*—Akin, Gump, Strauss, Hauer & Feld LLP

(57) **ABSTRACT**

The present invention relates to a high contrast reflective display comprising at least one substrate, at least one electrically conductive layer and at least one close-packed, ordered monolayer of domains of electrically modulated material in a fixed, preferably crosslinked, polymer matrix and a method of making the same.

41 Claims, 11 Drawing Sheets



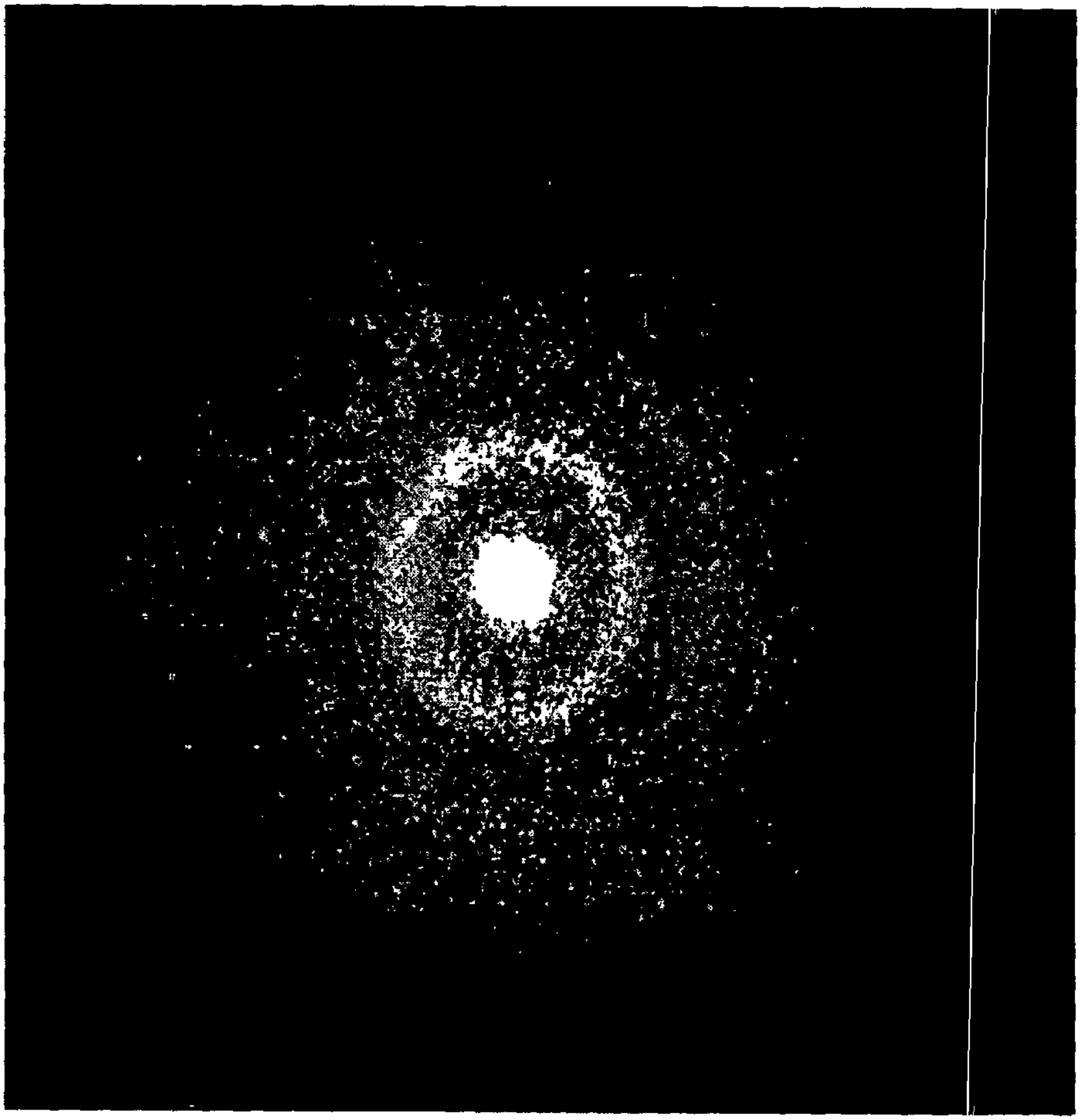


FIG. 1

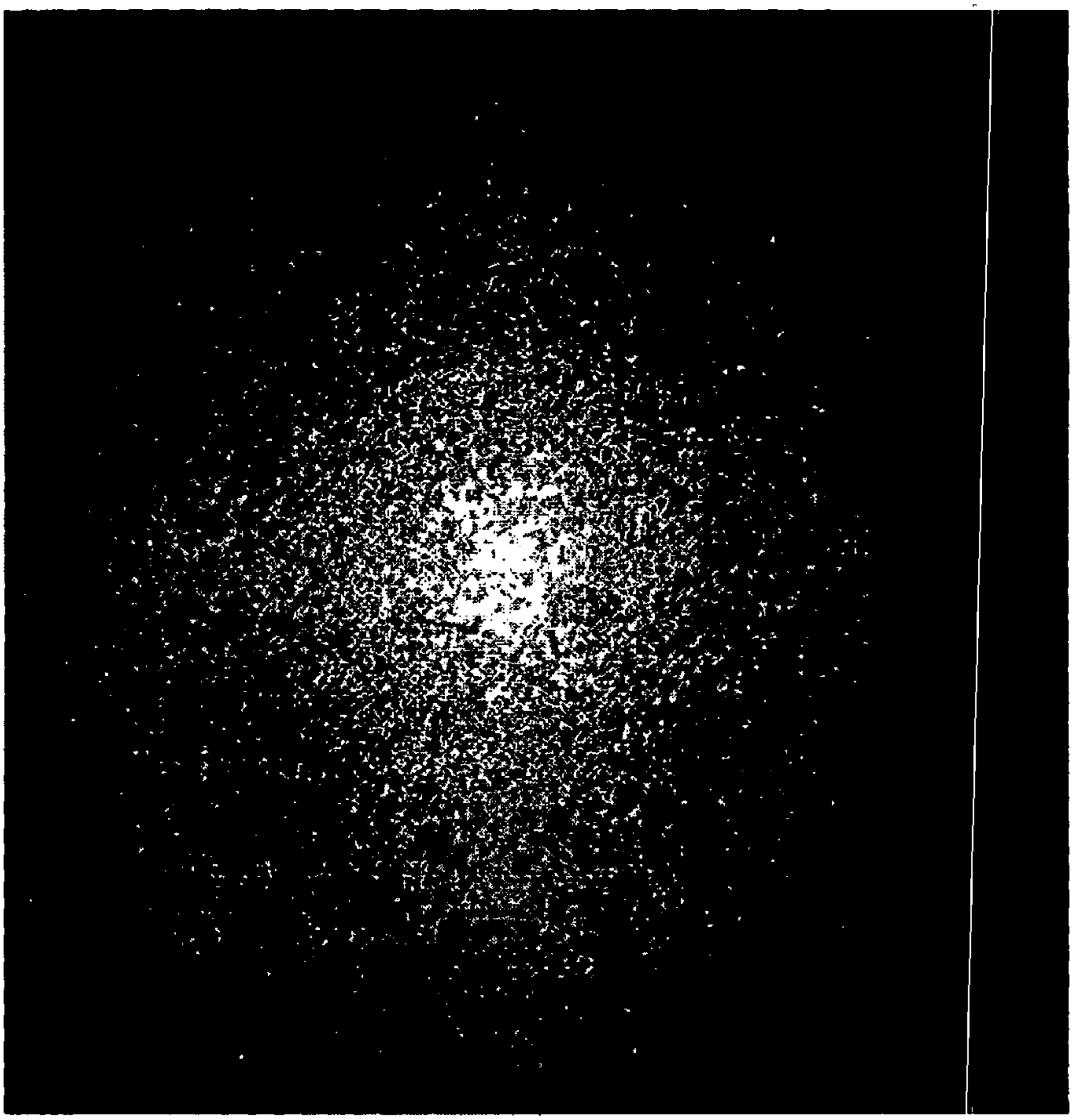
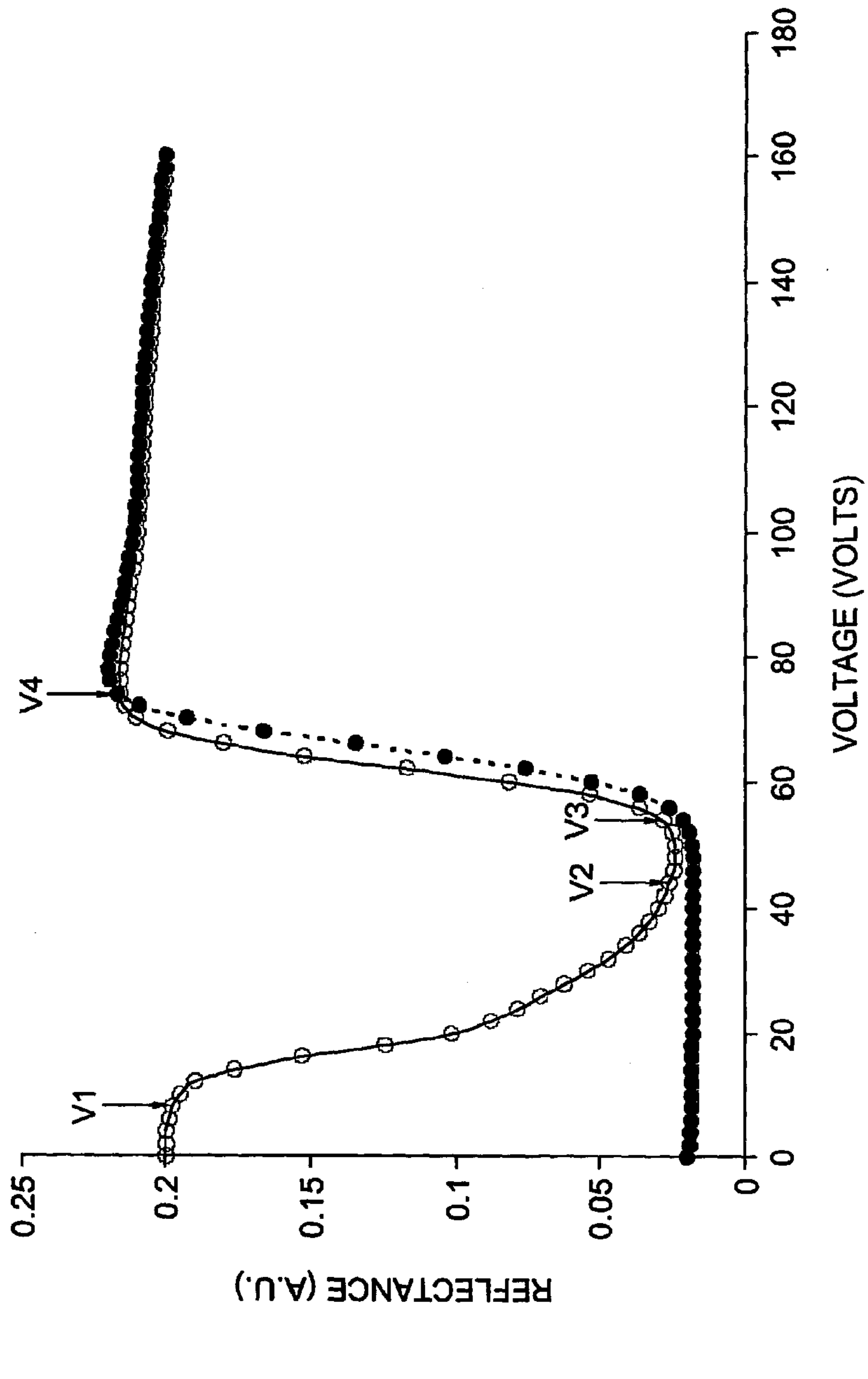


FIG. 2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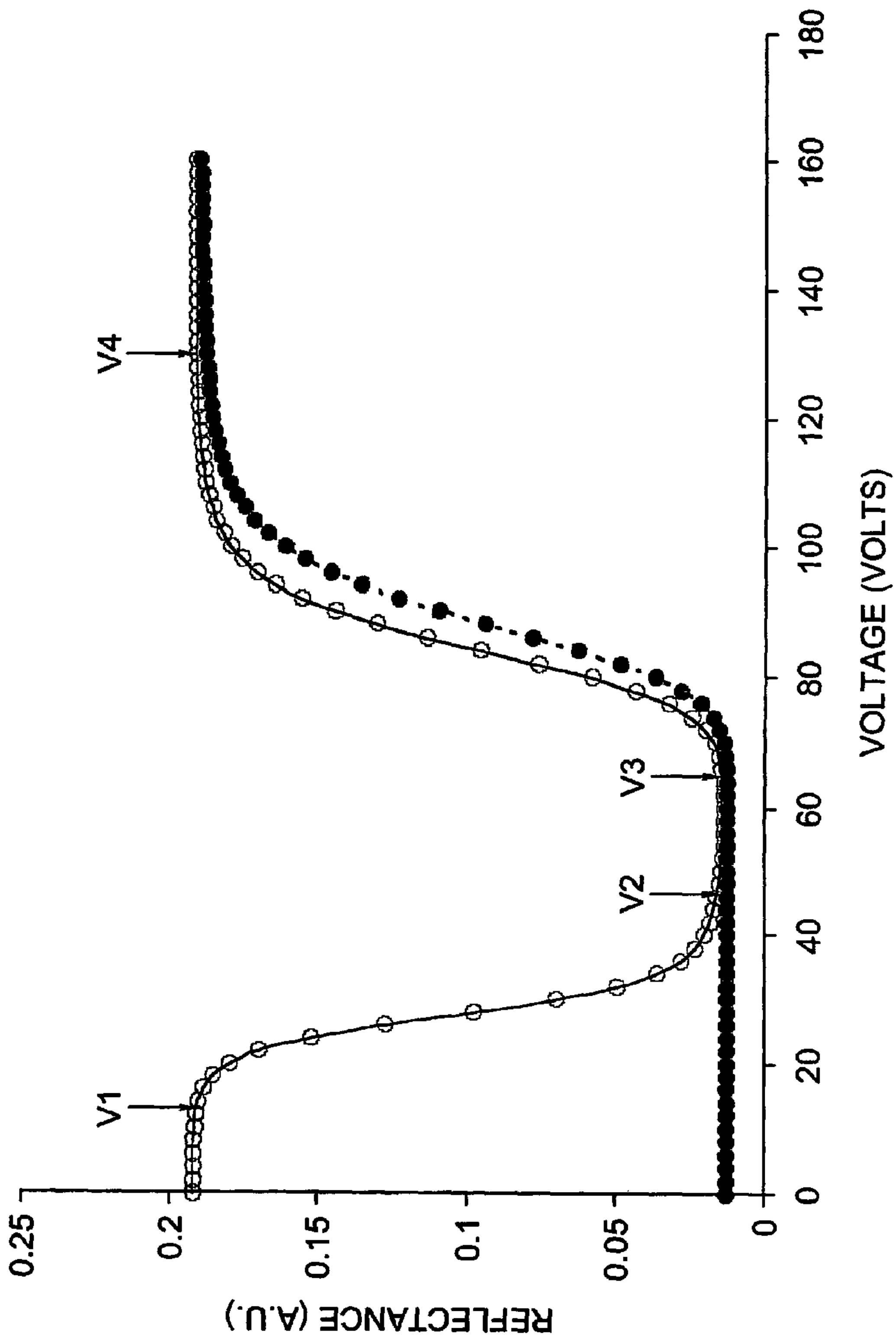
120
140
160
180
V1
V2
V3
V4

FIG. 3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120
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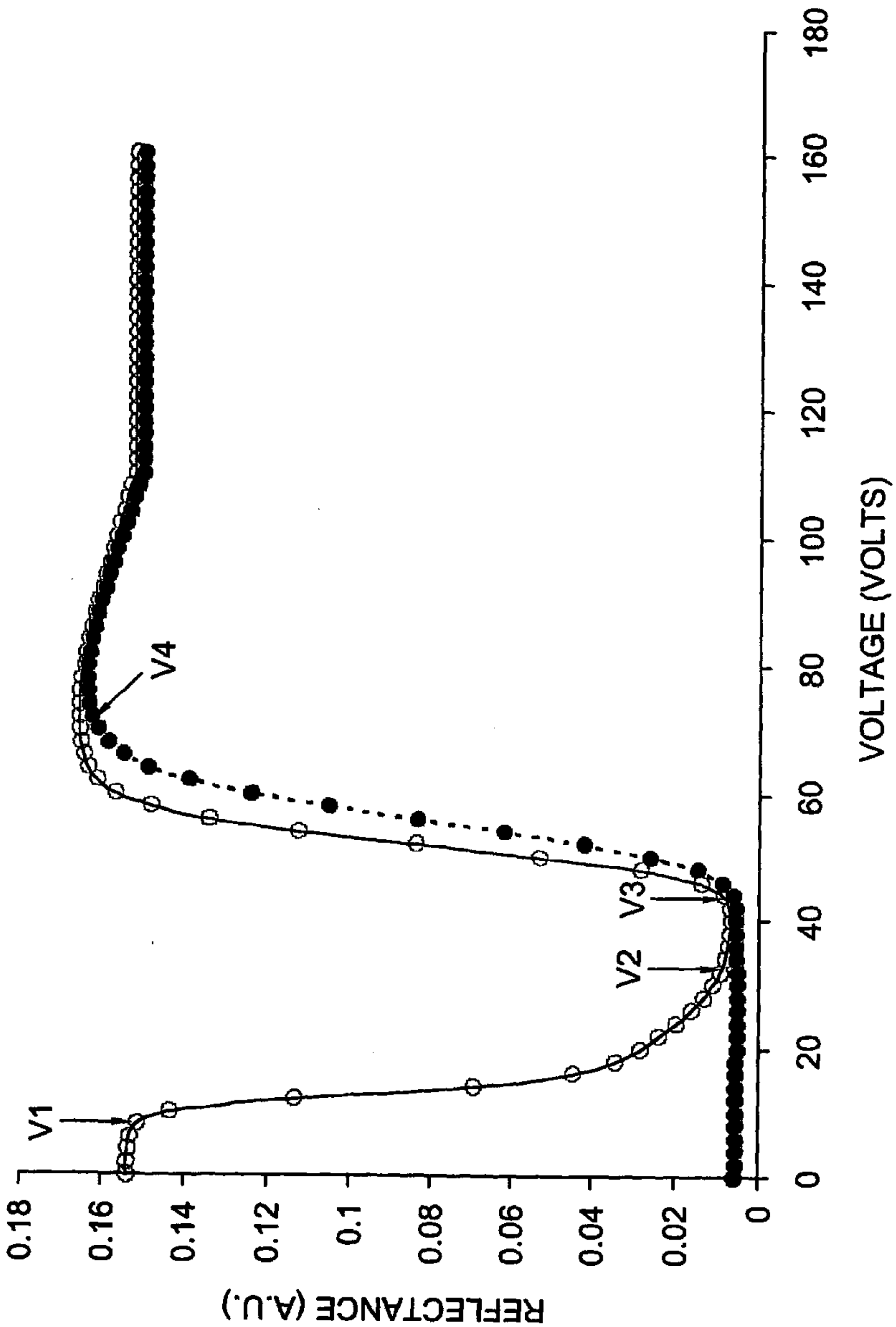
REFLECTANCE (A.U.)

FIG. 4


REFLECTANCE (A.U.)
0.18
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0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
VOLTAGE (VOLTS)
0
20
40
60
80
100
120
140
160
180
V1
V2
V3
V4

FIG. 5

within the scope of one or more claims of the '457 patent. The infringing instrumentalities have no substantial non-infringing uses.

92. As a direct and proximate result of Samsung's acts of patent infringement, ITRI has been and continues to be injured and has sustained and will continue to sustain substantial damages.

93. Unless Samsung is enjoined by this Court from continuing their infringement of the '457 patent, ITRI will suffer additional irreparable harm and impairment of the value of its patent rights.

94. ITRI has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and ITRI is entitled to recover its reasonable and necessary attorneys' fees, costs, and expenses.

XII. INFRINGEMENT OF U.S. PATENT NO. 7,339,197

95. On March 4, 2008, the USPTO issued U.S. Patent No. 7,339,197, entitled "Light Emitting Diode and Fabrication Method Thereof" (hereinafter "the '197 patent"). A true and correct copy of the '197 patent is attached hereto as Exhibit J.

96. ITRI is the owner of all right, title, and interest in and to the '197 patent by assignment, with full right to bring suit to enforce the patent, including the right to recover for past infringement damages and the right to recover future royalties, damages, and income.

97. The '197 patent is valid and enforceable.

98. All requirements under 35 U.S.C. § 287 have been satisfied with respect to the '197 patent.

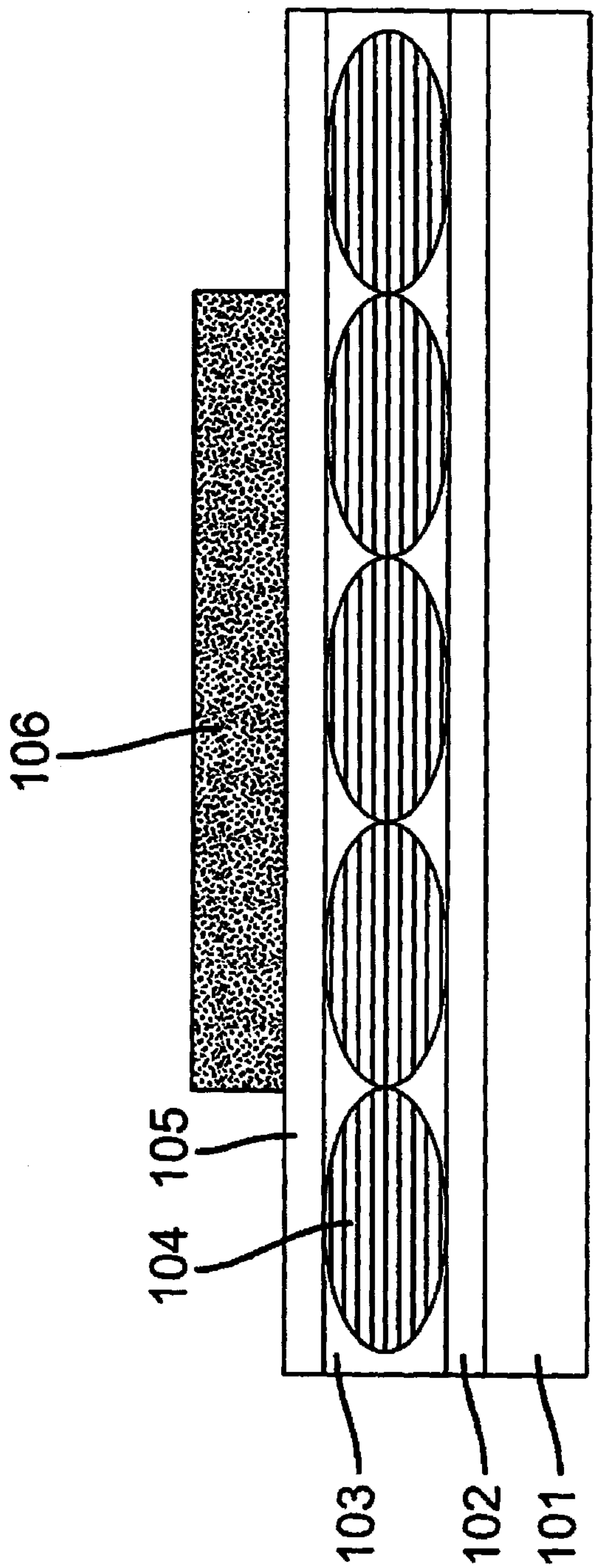


FIG. 6

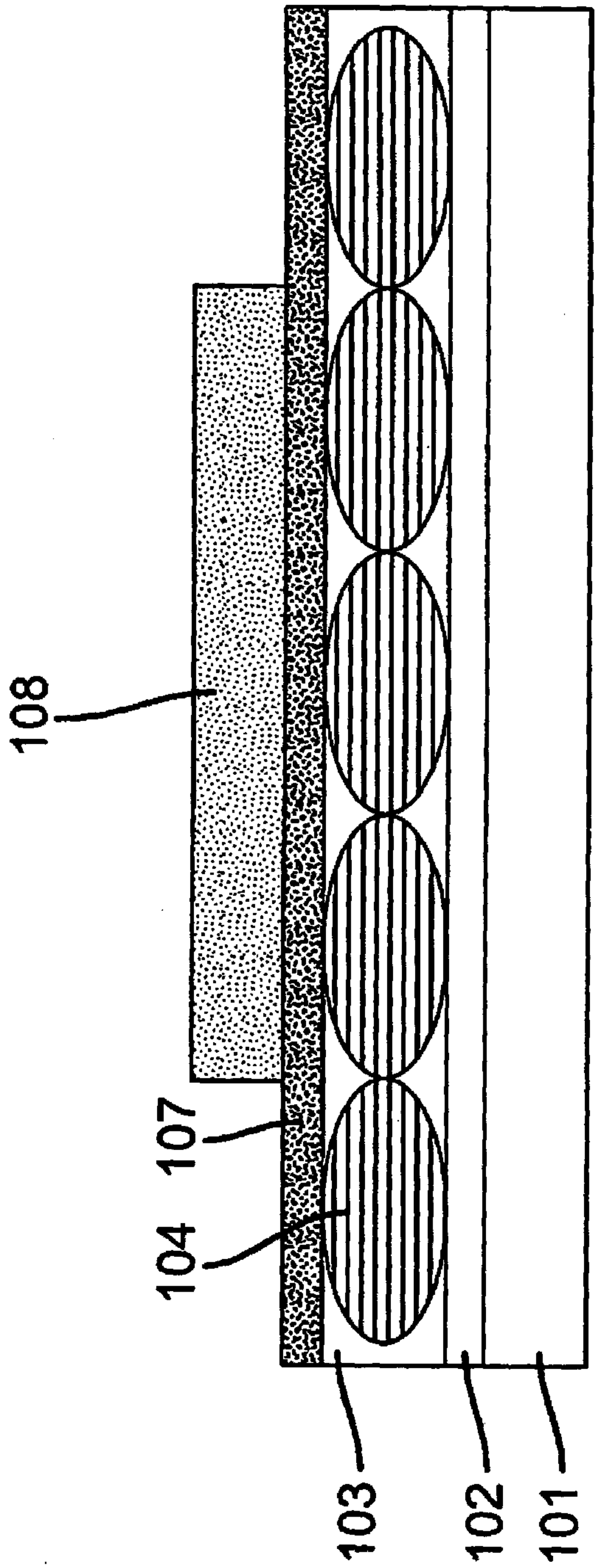


FIG. 7

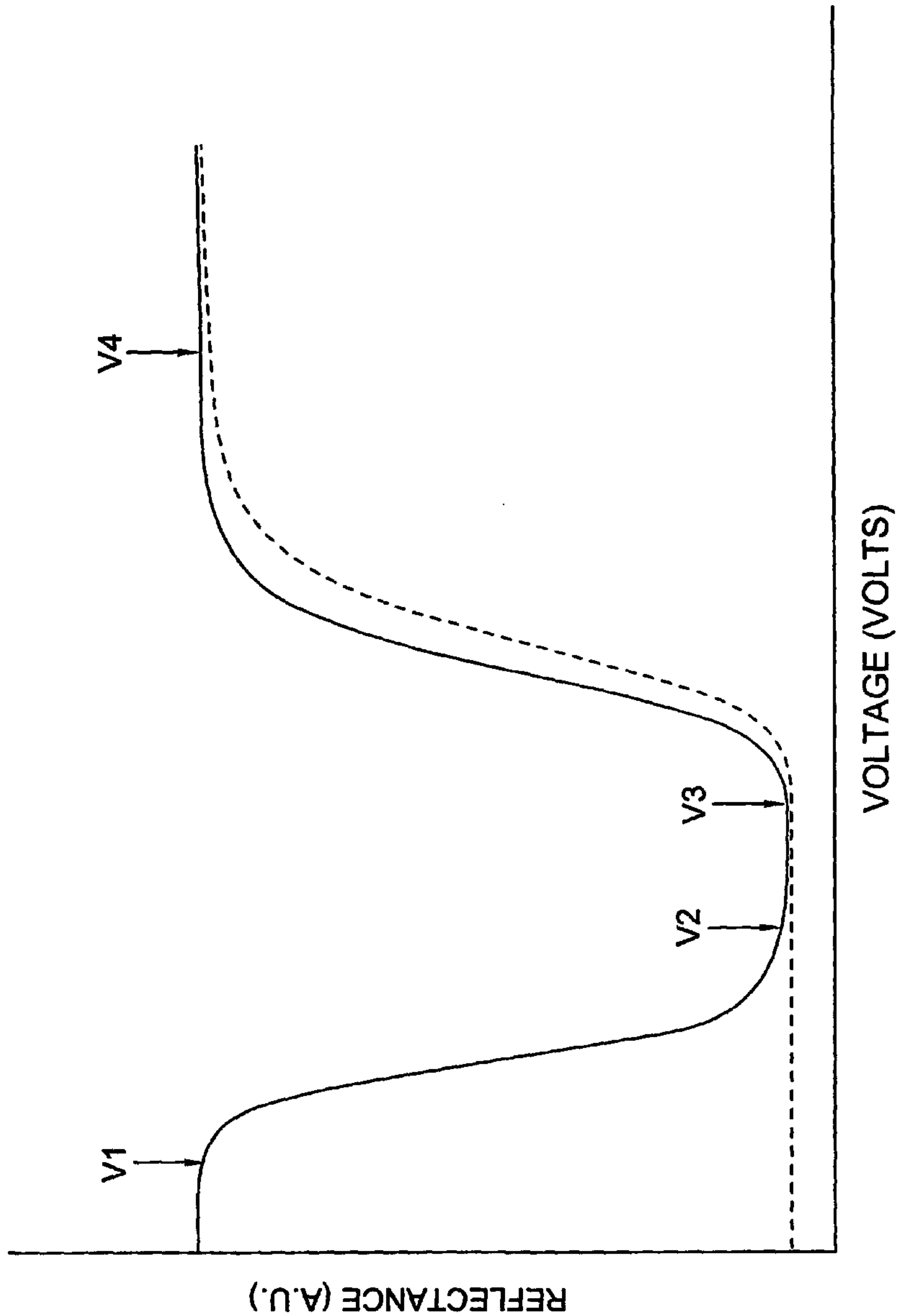


FIG. 8

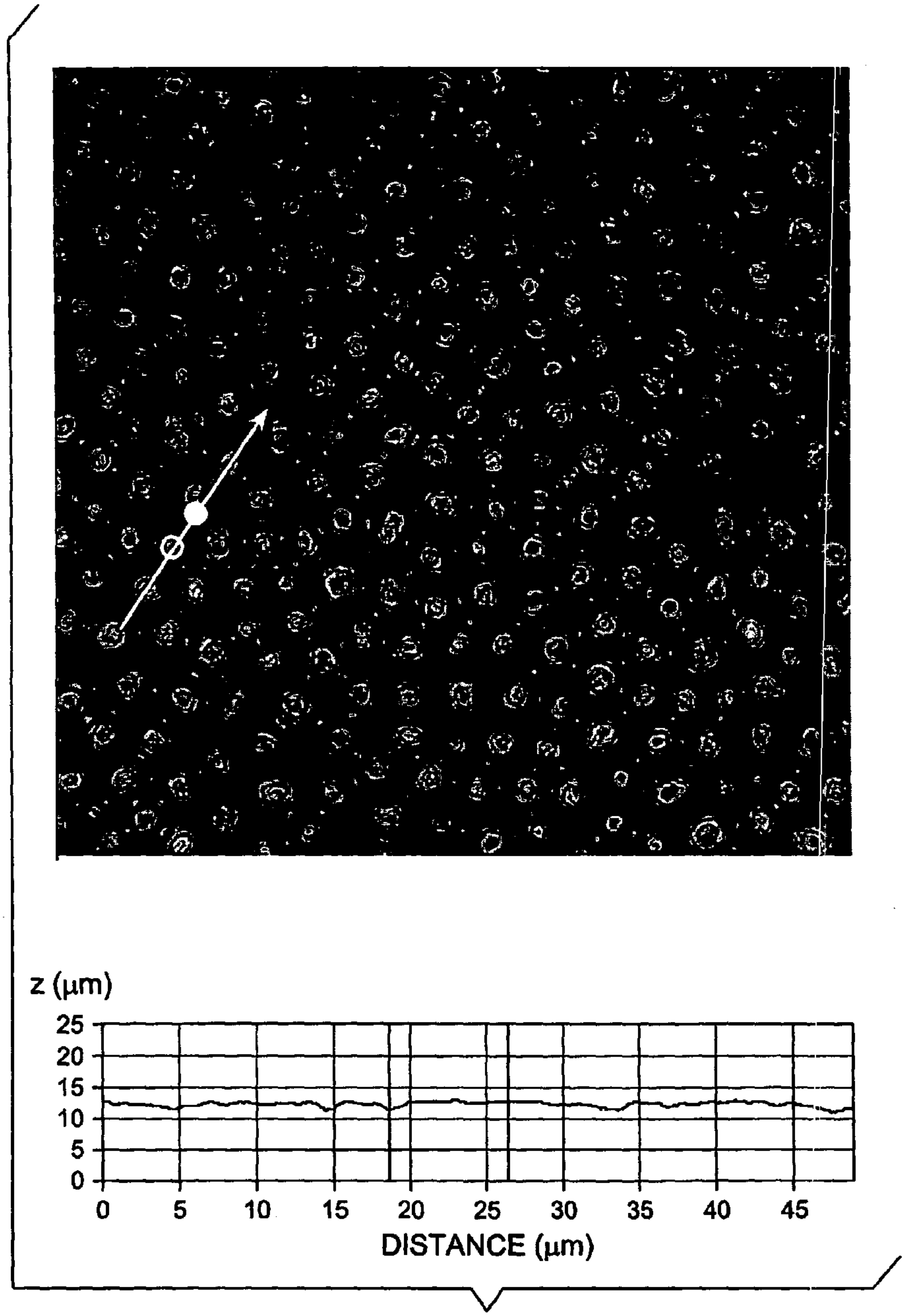
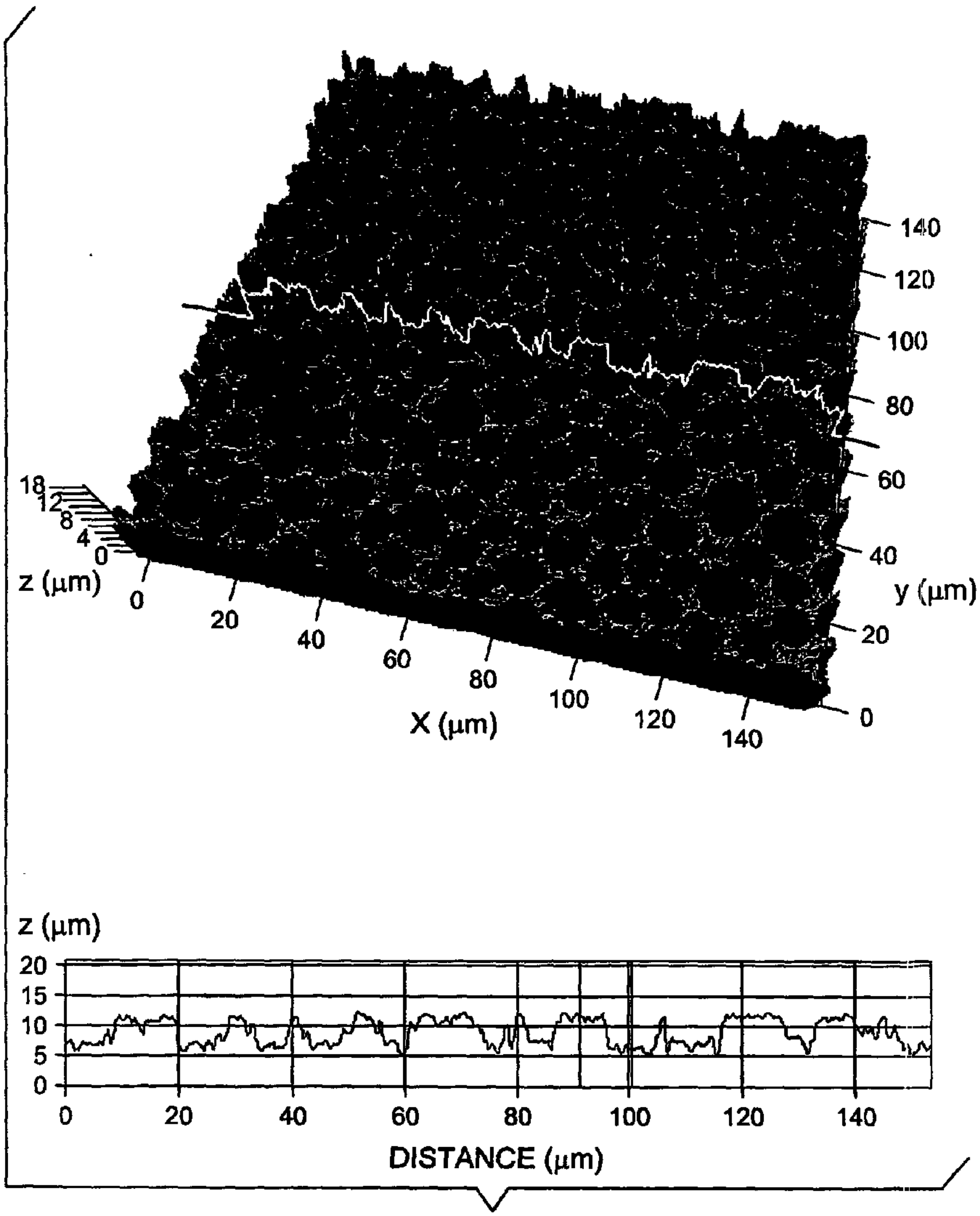


FIG. 9



18
12
8
4
0
z (μm)
0
20
40
60
80
100
120
140
X (μm)
0
20
40
60
80
100
120
140
y (μm)
z (μm)
20
15
10
5
0
0
20
40
60
80
100
120
140
DISTANCE (μm)

FIG. 10

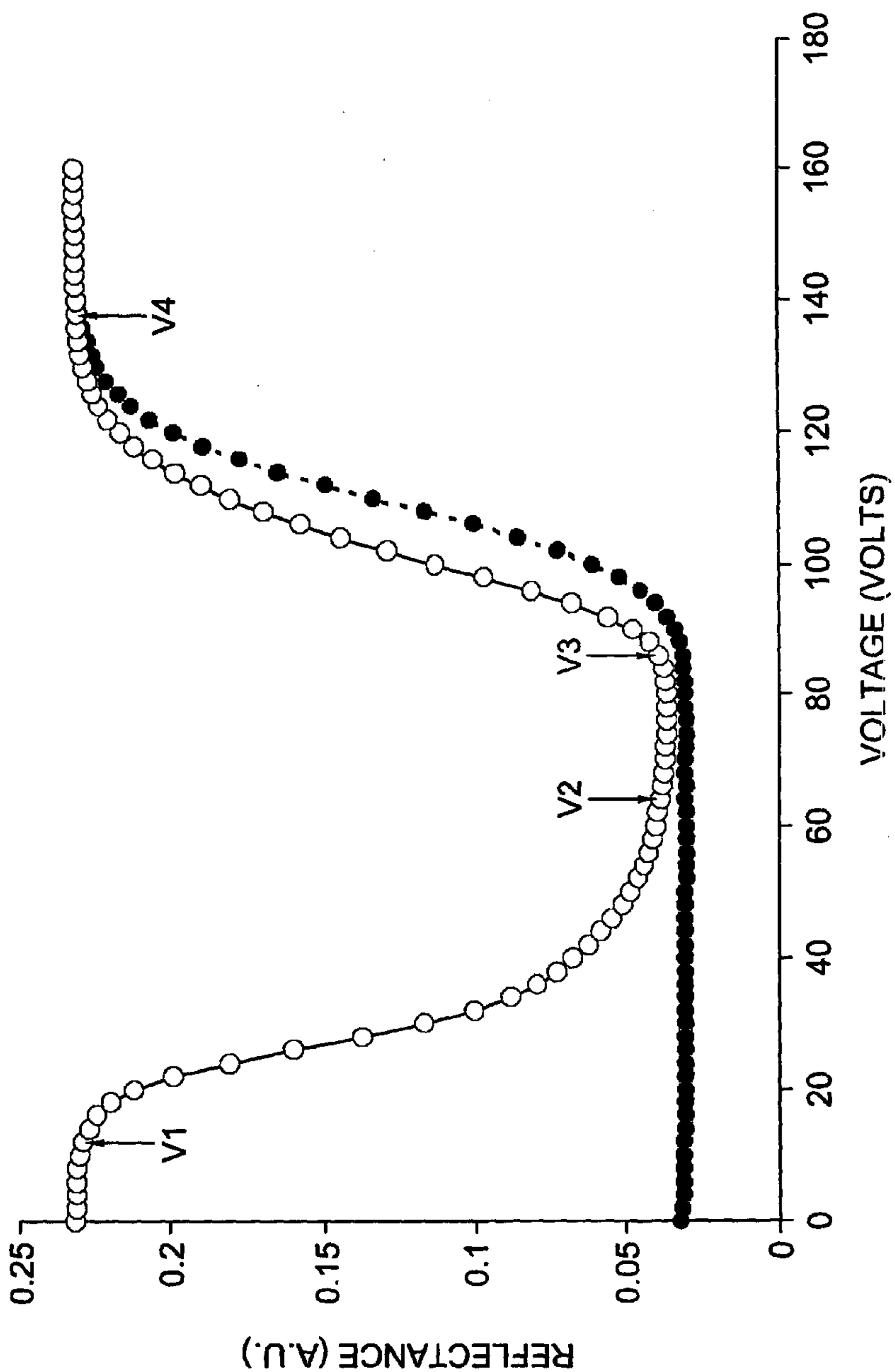

REFLECTANCE (A.U.)
0.25
0.2
0.15
0.1
0.05
0
VOLTAGE (VOLTS)
0
20
40
60
80
100
120
140
160
180
V1
V2
V3
V4

FIG. 11

REFLECTIVE DISPLAY BASED ON LIQUID CRYSTAL MATERIALS

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part of application Ser. No. 11/017,181, filed Dec. 20, 2004 now abandoned entitled "REFLECTIVE DISPLAY BASED ON LIQUID CRYSTAL MATERIALS" by Chari et al.

FIELD OF THE INVENTION

The present invention relates to a high contrast displays.

BACKGROUND OF THE INVENTION

There is significant interest in low cost flexible electronic displays. Typically, such displays comprise a light modulating component embedded in a binder (most commonly polymer) matrix that is coated over a conductive plastic support. Broadly speaking, a light modulating component is a material that changes its optical properties such as its ability to reflect or transmit light in response to an electric field. The light modulating component may be a liquid crystalline material such as a nematic liquid crystal, a chiral nematic or cholesteric liquid crystal or a ferroelectric liquid crystal. The light modulating material may also be a water insoluble liquid containing particles that undergo electrophoresis or motion such as rotation or translation in response to an electric field. Displays comprising a liquid crystalline material in a polymer matrix are referred to as polymer dispersed liquid crystal (PDLC) displays.

There are two main methods for fabricating PDLC devices: emulsion methods and phase separation methods. Emulsion methods have been described in U.S. Pat. Nos. 4,435,047 and 5,363,482. The liquid crystal is mixed with an aqueous solution containing polymer. The liquid crystal is insoluble in the continuous phase and an oil-in-water emulsion is formed when the composition is passed through a suitable shearing device, such as a homogenizer. The emulsion is coated on a conductive surface and the water allowed to evaporate. A second conductive surface may then be placed on top of the emulsion or imaging layer by lamination, vacuum deposition, or screen printing to form a device. While the emulsion methods are straightforward to implement, droplet size distributions tend to be broad resulting in a loss in performance. For cholesteric liquid crystal devices, also referred to herein as CLC devices, this typically means reduced contrast and brightness. Phase separation methods were introduced in an effort to overcome this difficulty.

Phase separation methods have been outlined in U.S. Pat. No. 4,688,900 and in Drzaic, P. S. in Liquid Crystal Dispersions, pgs. 30-51, published by World Scientific, Singapore (1995). The liquid crystal and polymer, or precursor to the polymer, are dissolved in a common organic solvent. The composition is then coated on a conductive surface and induced to phase separate by application of ultraviolet (UV) radiation or by the application of heat or by evaporation of the solvent, resulting in droplets of liquid crystal in a solid polymer matrix. A device may then be constructed utilizing this composition. Although phase separation methods produce dispersed droplets having more uniform size distributions, there are numerous problems with this approach. For example, the long term photostability of photopolymerized systems is a concern due to the presence of photoinitiators that produce reactive free radicals. Photoinitiators not consumed by the polymerization process can continue to produce free radicals that can degrade the polymer and liquid crystals over time. Furthermore, it is also known that UV radiation is harmful to liquid crystals. Specifically, exposure to UV radiation can lead to decomposition of the chiral dopant in a cholesteric liquid crystal mixture, resulting in a change in the reflected color. The use of organic solvents may also be objectionable in certain manufacturing environments.

U.S. Pat. Nos. 6,423,368 and 6,704,073 propose to overcome the problems associated with the prior art methods through the use of droplets of the liquid crystal material prepared using a limited coalescence process. In this process, the droplet-water interface is stabilized by particulate species, such as colloidal silica. Surface stabilization by particulate species such as colloidal silica is particularly preferred as it can give narrow size distribution and the size of the droplets can be controlled by the concentration of the particulate species employed. The materials prepared via this process are also referred to as Pickering Emulsions and are described more fully by Whitesides and Ross (J. Colloid Interface Sci. 169, 48 (1995)). The uniform droplets may be combined with a suitable binder and coated on a conductive surface to prepare a device. The process provides improvement in brightness and contrast over prior art processes. It also overcomes some of the problems associated with photoinitators and UV radiation. However, there is still much room for improvement, particularly in terms of the switching voltage or the voltage needed to change the orientation of the liquid crystal from one state to another. The latter has a significant effect on the overall cost of the display. A low switching voltage is extremely desirable for low cost displays.

The device described by U.S. Pat. Nos. 6,423,368 and 6,704,073 suffers from drawbacks because of the structure of the coated layer. Undesirably, there may be more than a monolayer of droplets between the two electrodes. Furthermore, the process of coating a heated emulsion of the liquid crystal in a gelatin binder onto a substrate with a conductive layer and subsequently lowering the temperature of the coating to change the state of the coated layer from a free flowing liquid to a gel state (referred to as a sol-gel transition) prior to drying the coating results in an extremely uneven distribution of droplets of liquid crystal. At the microscopic scale there are regions of the coating containing overlapping droplets and other regions with no droplets at all between the electrodes. The uneven distribution of droplets results in a decrease in contrast and an increase in switching voltage.

U.S. Pat. Nos. 6,271,898 and 5,835,174 also describe compositions suitable for flexible display applications that employ very uniform sized droplets of liquid crystal in a polymer binder. However, no attempt is made to control the thickness or the distribution of droplets in the coated layer resulting in less than optimum performance.

U.S. patent application Ser. No. 10/718,900 shows that the maximum contrast in a bistable chiral nematic liquid crystal display prepared by the limited coalescence method is obtained when the uniform liquid crystal domains or droplets are coated as substantially a monolayer on the first conductive support. The bistable states in these chiral nematic liquid crystal displays are the planar reflecting state and the weakly scattering focal conic state. Back-scattering of light from the weakly scattering focal conic state increases drastically when there is more than a monolayer of droplets between the conductive surfaces. While the method provides displays with an improvement in brightness and contrast, it

still falls short of optimum performance because the gelatin binder is made to undergo a sol-gel transition prior to drying of the coating resulting in an uneven structure.

Rudhardt et al. (Applied Physics Letters vol. 82, page 2610, 2003) describe a method of fabricating a light modulating device wherein a composition containing very uniform droplets of liquid crystal in an aqueous solution of polymer binder is spread on an indium tin oxide (ITO) coated glass surface and the water allowed to evaporate. The droplets of liquid crystal spontaneously self-assemble into a hexagonal close-packed (HCP) monolayer. A second ITO coated glass surface is placed over the coated layer of droplets as the top electrode to complete construction of the device. A uniform monolayer thickness is achieved for the coated layer and the close-packed distribution of droplets is also extremely well defined. Both features result in a low switching voltage. However, there are numerous problems with this approach. Firstly, the uniform droplets of liquid crystal are prepared by extrusion through a thin capillary into a flowing fluid. When a droplet at the tip of the capillary grows to reach critical size, viscous drag exceeds surface tension and breakoff occurs, producing highly monodisperse emulsions. Clearly, this method of creating one droplet at a time is not suitable for large scale manufacture. Secondly, the method by which the second (top) electrode is applied may be suitable for construction of small scale displays on rigid substrates such as glass but is not viable for large area low cost displays on flexible substrates.

US 2003/0137717A1 and US 2004/0217929A1 indicate that a close-packed monolayer of droplets of the light modulating component may be desirable for obtaining high brightness and contrast in a polymer dispersed electrophoretic display. However the method of making droplets described in these applications is a standard emulsification process that does not result in emulsions having a narrow size distribution that is desirable for obtaining close-packed monolayers by spontaneous self-assembly. The preferred method of preparing droplets in US 2003/0137717A1 and US 2004/0217929A1 also involves encapsulation resulting in droplets or capsules in the size range of 20 to 200 microns with wall thickness of 0.2 to 10 microns. The relatively large droplet size and wall thickness result in high switching voltages. The latter is particularly a problem for bistable CLC devices. Encapsulation is clearly not desirable but these applications do not teach how a second conducting layer is to be applied on top of the coated layer of droplets in the absence of encapsulation. In the absence of encapsulation, droplets of the light modulating component may directly come in contact with the organic solvent in the screen printed conducting ink leading to contamination or poisoning of the light modulating component. This is particularly a concern if the light modulating component is a liquid crystal material.

To overcome the difficulties of US 2003/0137717A1 and US 2004/0217929A1, US 2004/0226820A1 teaches that a close-packed monolayer of droplets may be obtained by using electro-deposition followed by washing after the droplets have been spread on a suitable surface using a coating knife or coating head such as a slot die coating head. However, the additional steps of electro-deposition and washing are cumbersome and not suitable for manufacturing on a large scale. Even with these additional steps, a close-packed monolayer of uniform thickness is not achieved. The root mean square (RMS) surface roughness is about 6 microns because of non-uniform droplets or capsules. This is a very high value of surface roughness that would result in irregular or incomplete curing if a UV curable screen

printed conducive ink is used as the second electrode. The irregular curing will result in increased switching voltages. Furthermore, a surface roughness of this magnitude will also result in significant non-uniformity of switching voltage across the area of the display since the switching voltage is directly related to the thickness of the coated layer.

US 2003/0137717A1, US 2004/0217929A1 and US 2004/0226820A1 also teach using polymer latex as the preferred binder. The use of polymer latex materials is not desirable for a number of reasons. Many commercial latex materials contain high boiling organic co-solvents that render them unsuitable for use in PDLC films due to the poisoning effect the solvents have on the liquid crystal or other light modulating component. This is particularly true if the droplets are not encapsulated as is desirable from the point of view of reduced switching voltage. Latex polymers also have an affinity for the liquid crystal or other light modulating component leading to dissolution of the light modulating component into the polymer matrix. Furthermore, if the latex is not fully transparent, it can lead to a loss of contrast. Other binders suggested in US 2004/0217929A1 such as acrylics or polyvinylalcohol are difficult to fix or cross-link if used alone. Fixing or cross-linking is desired in order to preserve the close-packed monolayer structure when other layers are spread over it.

U.S. Pat. No. 5,847,798 discloses a liquid crystalline light modulating cell and material, characterized by liquid crystalline light modulating material of liquid crystal and polymer, the liquid crystal being a chiral nematic liquid crystal having positive dielectric anisotropy and including chiral material in an amount effective to form focal conic and twisted planar textures, the polymer being distributed in phase separated domains in the liquid crystal cell in an amount that stabilizes the focal conic and twisted planar textures in the absence of a field and permits the liquid crystal to change textures upon the application of a field. In one embodiment, the material is light scattering in a field-OFF condition and optically clear in a field-ON condition, while in another embodiment, the material is optically clear in a field-OFF condition and light scattering in a field-ON condition. In still another embodiment, a black-white cholesteric reflective display can be realized by employing a polymer concentration of about three percent based on the combined weight of all the material contained within the cell. A cholesteric material which has an intrinsic pitch of about 600 nm results in a display which appears much like a newspaper or book page. In other words, by selecting in combination the proper polymer concentration and intrinsic pitch of the liquid crystal material, a substantially white page or surface with black characters thereon can be obtained. This embodiment allows for a display with a substantially white background with substantially black characters much like a printed page. However, this embodiment has a cell consisting of two substrates, one on either side of the liquid crystal polymer film.

U.S. Pat. No. 6,833,891 discloses a reflective liquid crystal display (LCD) including a cholesteric liquid crystal polarizing device and a liquid crystal cell superimposed with one another. In various embodiments, the reflective LCD may be a normally white mode or normally black mode device. In another variation, the liquid crystal cell may include a 90° twisted nematic liquid crystal. Unlike the current invention, this invention includes a 90 degree twisted nematic LCD to modulate the light output.

U.S. Pat. Publ. No. 2004/0223098 discloses a display device displaying a color by mixing light reflected by a first reflection element and light reflected by a second reflection

element by additive color mixture, in which the light of a first wavelength reflected by the first reflection element and light of a second wavelength reflected by the second reflection element have a mutually complementary color relationship. Thus, the display device, which can make good black and white display by a simple structure and can be driven by a simple method, can be realized. Unlike the current invention, this invention has 2 layers of cholesteric, for instance one blue and one yellow, using additive color the mixture is white.

U.S. Pat. Publ. No. 2004/0125284 discloses a chiral nematic display configuration, typically in liquid crystal displays, comprising a chiral nematic display of controllable planar structure and focal conic structure, characterised by the chiral nematic liquid crystal material being between two transparent substrates having conductive electrodes, the material being between two elliptical polarizers and there being an optical reflector. The invention achieves a high contrast black-and-white display. The displays in the embodiment are first and second optical mode configurations of the black-and-white chiral nematic displays. Unlike the current invention, this invention utilizes elliptical polarizers on either side of the cholesteric liquid crystal to absorb or transmit the light transmitted by the cholesteric liquid crystal.

For these reasons, an alternative approach is clearly needed.

PROBLEM TO BE SOLVED

There remains a need for a reduced cost, display having excellent brightness, high contrast, and low switching voltage.

SUMMARY OF THE INVENTION

The present invention relates to a high contrast reflective display comprising at least one substrate, at least one electrically conductive layer and at least one close-packed, ordered monolayer of domains of electrically modulated material in a fixed polymer matrix and a method of making the same.

ADVANTAGEOUS EFFECT OF THE INVENTION

The present invention includes several advantages, not all of which are incorporated in a single embodiment. The current single substrate displays have a small distribution of wavelengths reflected this will allow for broadband reflection and black for the dark state. This is much more pleasing so the eye then monochrome displays. By selecting, in combination with the light modulating material with an intrinsic pitch, a UV curable polymer in a proper concentration, a substantially white page or surface with black characters thereon can be obtained. Accordingly, the black-white cholesteric reflective display provides a pleasing appearance and reduced eyestrain while reading the characters on the display when compared to other currently known liquid crystal reflective displays, while being pressure insensitive and using one substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 represents the diffraction pattern caused by Fraunhofer diffraction of light indicating a close-packed ordered monolayer of chiral nematic liquid crystal (CLC) droplets (or droplets of the light modulating material) in the coating of the invention.

FIG. 2 represents the diffraction pattern by Fraunhofer diffraction of light indicating a very disordered coating of the CLC droplets, according to the prior art.

FIG. 3 illustrates the electro-optic response of a display device based on one embodiment of the method of the invention.

FIG. 4 illustrates the electro-optic response of a display device based on the method of the prior art.

FIG. 5 illustrates the electro-optic response of a display device based on a second embodiment of the method of the invention.

FIG. 6 illustrates a display based on one embodiment of the invention.

FIG. 7 illustrates a display based on a second embodiment of the invention.

FIG. 8 illustrates a typical response of a bistable cholesteric or chiral nematic liquid crystal material to voltage pulses.

FIG. 9 illustrates the uniformity of the surface of the coated layer of the light modulating component prepared according to the method of the invention.

FIG. 10 illustrates fixing the architecture of the coated layer of the light modulating component of uniform thickness according to the method of the invention.

FIG. 11 illustrates the electro-optic response of a display device using polymer latex as binder in the imaging layer.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to a high contrast reflective display comprising at least one substrate, at least one electrically conductive layer and at least one close-packed, ordered monolayer of domains of electrically modulated material in a fixed, preferably crosslinked, polymer matrix and a method of making the same. In the preferred embodiment, the electrically modulated material is a chiral nematic liquid crystal incorporated in a polymer matrix. Chiral nematic liquid crystalline materials may be used to create electronic displays that are both bistable and viewable under ambient lighting. Furthermore, the liquid crystalline materials may be dispersed as micron sized droplets in an aqueous medium, mixed with a suitable binder material and coated on a flexible conductive support to create potentially low cost displays. The operation of these displays is dependent on the contrast between the planar reflecting state and the weakly scattering focal conic state. In order to derive the maximum contrast from these displays, it is desired that the chiral nematic liquid crystal domains or droplets are spread on a conductive support as a close-packed ordered monolayer. It is possible to prepare such an ordered monolayer by first applying an aqueous dispersion of chiral nematic liquid crystal domains to the substrate in the presence of a suitable binder, allowing the domains or droplets to self-assemble into a close-packed ordered monolayer, preferably a hexagonal close-packed (HCP) monolayer and then allowing the binder material to set, become fixed or crosslink to preserve the close-packed ordered monolayer structure so that other aqueous layers can be spread above the imaging layer without affecting the close-packed structure.

In general, the light modulating imaging layer contains electrically modulated material domains dispersed in a binder. For purposes of the present invention domains are defined to be synonymous with micelles and/or droplets. The

electrically modulated material may be electrochromic material, rotatable microencapsulated microspheres, liquid crystal materials, cholesteric/chiral nematic liquid crystal materials, polymer dispersed liquid crystals (PDLC), polymer stabilized liquid crystals, surface stabilized liquid crystals, smectic liquid crystals, ferroelectric material, electroluminescent material or any other of a very large number of light modulating imaging materials known in the prior art. The domains of the electrically modulated imaging layer include droplets having uniform domain size, with few, if any, parasitic domains, which are domains with random or uncontrolled sizes and which have undesirable electro-optical properties, within the dried coatings, as described in previous patent art.

The display includes a suitable electrically modulated material disposed on a suitable support structure, such as on or between one or more electrodes. The term "electrically modulated material" as used herein is intended to include any suitable nonvolatile material. Suitable materials for the electrically modulated material are described in U.S. patent application Ser. No. 09/393,553 and U.S. Provisional Patent Application Ser. No. 60/099,888, the contents of both applications are herein incorporated by reference.

The electrically modulated material may also be an arrangement of particles or microscopic containers or microcapsules. Each microcapsule contains an electrophoretic composition of a fluid, such as a dielectric or emulsion fluid, and a suspension of colored or charged particles or colloidal material. According to one practice, the particles visually contrast with the dielectric fluid. According to another example, the electrically modulated material may include rotatable balls that can rotate to expose a different colored surface area, and which can migrate between a forward viewing position and/or a rear nonviewing position, such as gyricon. Specifically, gyricon is a material comprised of twisting rotating elements contained in liquid filled spherical cavities and embedded in an elastomer medium. The rotating elements may be made to exhibit changes in optical properties by the imposition of an external electric field. Upon application of an electric field of a given polarity, one segment of a rotating element rotates toward, and is visible by an observer of the display. Application of an electric field of opposite polarity, causes the element to rotate and expose a second, different segment to the observer. A gyricon display maintains a given configuration until an electric field is actively applied to the display assembly. Gyricon materials are disclosed in U.S. Pat. Nos. 6,147,791, 4,126,854 and 6,055,091, the contents of which are herein incorporated by reference.

According to one practice, the microcapsules may be filled with electrically charged white particles in a black or colored dye. Examples of electrically modulated material suitable for use with the present invention are set forth in International Patent Application Publication Number WO 98/41899, International Patent Application Publication Number WO 98/19208, International Patent Application Publication Number WO 98/03896, and International Patent Application Publication Number WO 98/41898, the contents of which are herein incorporated by reference.

The electrically modulated material may also include material disclosed in U.S. Pat. No. 6,025,896, the contents of which are incorporated herein by reference. This material comprises charged particles in a liquid dispersion medium encapsulated in a large number of microcapsules. The charged particles can have different types of color and charge polarity. For example white positively charged particles can be employed along with black negatively charged particles. The described microcapsules are disposed between a pair of electrodes, such that a desired image is formed and displayed by the material by varying the dispersion state of the charged particles. The dispersion state of the charged particles is varied through a controlled electric field applied to the electrically modulated material.

Further, the electrically modulated material may include a thermochromic material. A thermochromic material is capable of changing its state alternately between transparent and opaque upon the application of heat. In this manner, a thermochromic imaging material develops images through the application of heat at specific pixel locations in order to form an image. The thermochromic imaging material retains a particular image until heat is again applied to the material. Since the rewritable material is transparent, UV fluorescent printings, designs and patterns underneath can be seen through.

The electrically modulated material may also include surface stabilized ferroelectric liquid crystals (SSFLC). Surface stabilized ferroelectric liquid crystals confining ferroelectric liquid crystal material between closely spaced glass plates to suppress the natural helix configuration of the crystals. The cells switch rapidly between two optically distinct, stable states simply by alternating the sign of an applied electric field.

Magnetic particles suspended in an emulsion comprise an additional imaging material suitable for use with the present invention. Application of a magnetic force alters pixels formed with the magnetic particles in order to create, update or change human and/or machine readable indicia. Those skilled in the art will recognize that a variety of bistable nonvolatile imaging materials are available and may be implemented in the present invention.

The electrically modulated material may also be configured as a single color, such as black, white or clear, and may be fluorescent, iridescent, bioluminescent, incandescent, ultraviolet, infrared, or may include a wavelength specific radiation absorbing or emitting material. There may be multiple layers of electrically modulated material. Different layers or regions of the electrically modulated material may have different properties or colors. Moreover, the characteristics of the various layers may be different from each other. For example, one layer can be used to view or display information in the visible light range, while a second layer responds to or emits ultraviolet light. The nonvisible layers may alternatively be constructed of nonelectrically modulated material based materials that have the previously listed radiation absorbing or emitting characteristics. The electrically modulated material employed in connection with the present invention preferably has the characteristic that it does not require power to maintain display of indicia.

The most preferred electrically modulated material is a light modulating material, such as a liquid crystalline material. The liquid crystalline material can be one of many different liquid crystal phases such as; nematic (N), chiral nematic (N*), or smectic, depending upon the arrangement of the molecules in the mesophase. Chiral nematic liquid crystal (N*LC) displays are preferably reflective, that is, no backlight is needed, and can function without the use of polarizing films or a color filter.

Chiral nematic liquid crystal refers to the type of liquid crystal having finer pitch than that of twisted nematic and super twisted nematic used in commonly encountered liquid crystal devices. Chiral nematic liquid crystals are so named because such liquid crystal formulations are commonly obtained by adding chiral agents to host nematic liquid crystals. Chiral nematic liquid crystals may be used to

99. Samsung has been and is infringing the '197 patent by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '197 patent, including but not limited to Samsung products bearing flat panel displays such as the Samsung netbook NP-N310-KA04US and notebook X460-41S.

100. Samsung has been and is continuing to induce infringement of the '197 patent under 35 U.S.C. § 271(b) and contributes to the infringement of the '197 patent under 35 U.S.C. § 271(c), in conjunction with such acts of making, using, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '197 patent. The infringing instrumentalities have no substantial non-infringing uses.

101. Samsung had and continues to have actual knowledge of the '197 patent and their coverage of Samsung's infringing instrumentalities, but has nonetheless engaged in the infringing conduct. Samsung's infringement of the '197 patent was and continues to be willful.

102. As a direct and proximate result of Samsung's acts of patent infringement, ITRI has been and continues to be injured and has sustained and will continue to sustain substantial damages.

103. Unless Samsung is enjoined by this Court from continuing their infringement of the '197 patent, ITRI will suffer additional irreparable harm and impairment of the value of its patent rights.

104. ITRI has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case

produce bistable or multi-stable displays. These devices have significantly reduced power consumption due to their nonvolatile "memory" characteristic. Since such displays do not require a continuous driving circuit to maintain an image, they consume significantly reduced power. Chiral nematic displays are bistable in the absence of a field, the two stable textures are the reflective planar texture and the weakly scattering focal conic texture. In the planar texture, the helical axes of the chiral nematic liquid crystal molecules are substantially perpendicular to the substrate upon which the liquid crystal is disposed. In the focal conic state the helical axes of the liquid crystal molecules are generally randomly oriented. Adjusting the concentration of chiral dopants in the chiral nematic material modulates the pitch length of the mesophase and, thus, the wavelength of radiation reflected. Chiral nematic materials that reflect infrared radiation and ultraviolet have been used for purposes of scientific study. Commercial displays are most often fabricated from chiral nematic materials that reflect visible light. Some known LCD devices include chemically etched, transparent, conductive layers overlying a glass substrate as described in U.S. Pat. No. No. 5,667,853, incorporated herein by reference. Suitable chiral nematic liquid crystal compositions preferably have a positive dielectric anisotropy and include chiral material in an amount effective to form focal conic and twisted planar textures. Chiral nematic liquid crystal materials are preferred because of their excellent reflective characteristics, bistability and gray scale memory.

Modern chiral nematic liquid crystal materials usually include at least one nematic host combined with a chiral dopant. In general, the nematic liquid crystal phase is composed of one or more mesogenic components combined to provide useful composite properties. The nematic component of the chiral nematic liquid crystal mixture may be comprised of any suitable nematic liquid crystal mixture or composition having appropriate liquid crystal characteristics. Nematic liquid crystals suitable for use in the present invention are preferably composed of compounds of low molecular weight selected from nematic or nematogenic substances, for example from the known classes of the azoxybenzenes, benzylideneanilines, biphenyls, terphenyls, phenyl or cyclohexyl benzoates, phenyl or cyclohexyl esters of cyclohexanecarboxylic acid, phenyl or cyclohexyl esters of cyclohexylbenzoic acid, phenyl or cyclohexyl esters of cyclohexylcyclohexanecarboxylic acid, cyclohexylphenyl esters of benzoic acid, of cyclohexanecarboxylic acid and of cyclohexylcyclohexanecarboxylic acid, phenyl cyclohexanes, cyclohexylbiphenyls, phenyl cyclohexylcyclohexanes, cyclohexylcyclohexanes, cyclohexylcyclohexenes, cyclohexylcyclohexylcyclohexenes, 1,4-bis-cyclohexylbenzenes, 4,4-bis-cyclohexylbiphenyls, phenyl- or cyclohexylpyrimidines, phenyl- or cyclohexylpyridines, phenyl- or cyclohexylpyridazines, phenyl- or cyclohexyldioxanes, phenyl- or cyclohexyl-1,3-dithianes, 1,2-diphenylethanes, 1,2-dicyclohexylethanes, 1-phenyl-2-cyclohexylethanes, 1-cyclohexyl-2-(4-phenylcyclohexyl)ethanes, 1-cyclohexyl-2',2-biphenylethanes, 1-phenyl-2-cyclohexylphenylethanes, optionally halogenated stilbenes, benzyl phenyl ethers, tolanes, substituted cinnamic acids and esters, and further classes of nematic or nematogenic substances. The 1,4-phenylene groups in these compounds may also be laterally mono- or difluorinated. The liquid crystalline material of this preferred embodiment is based on the achiral compounds of this type. The most important compounds, that are possible as components of these liquid crystalline materials, can be characterized by the following formula R'—X—Y—Z—R" wherein X and Z, which may be identical or different, are in each case, independently from one another, a bivalent radical from the group formed by -Phe-, -Cyc-, -Phe-Phe-, -Phe-Cyc-, -Cyc-Cyc-, -Pyr-, -Dio-, —B-Phe- and —B-Cyc-, wherein Phe is unsubstituted or fluorine-substituted 1,4-phenylene, Cyc is trans-1,4-cyclohexylene or 1,4-cyclohexenylene, Pyr is pyrimidine-2,5-diyl or pyridine-2,5-diyl, Dio is 1,3-dioxane-2,5-diyl, and B is 2-(trans-1,4-cyclohexyl)ethyl, pyrimidine-2,5-diyl, pyridine-2,5-diyl or 1,3-dioxane-2,5-diyl. Y in these compounds is selected from the following bivalent groups —CH=CH—, —C≡C—, —N=N(O)—, —CH=CY'—, —CH=N(O)—, —CH2—CH2—, —CO—O—, —CH2—O—, —CO—S—, —CH2—S—, —COO-Phe-COO— or a single bond, with Y' being halogen, preferably chlorine, or —CN. R' and R" are, in each case, independently of one another, alkyl, alkenyl, alkoxy, alkenyloxy, alkanoyloxy, alkoxycarbonyl or alkoxycarbonyloxy with 1 to 18, preferably 1 to 12 C atoms, or alternatively one of R' and R" is —F, —CF3, —OCF3, —Cl, —NCS or —CN. In most of these compounds R' and R' are, in each case, independently of each another, alkyl, alkenyl or alkoxy with different chain length, wherein the sum of C atoms in nematic media generally is between 2 and 9, preferably between 2 and 7. The nematic liquid crystal phases typically consist of 2 to 20, preferably 2 to 15 components. The above list of materials is not intended to be exhaustive or limiting. The lists disclose a variety of representative materials suitable for use or mixtures, which comprise the active element in light modulating liquid crystal compositions. Chiral nematic liquid crystal materials and cells, as well as polymer stabilized chiral nematic liquid crystals and cells, are well known in the art and described in, for example, U.S. patent application Ser. Nos. 07/969,093, 08/057,662, Yang et al., Appl. Phys. Lett. 60(25) pp 3102-04 (1992), Yang et al., J. Appl. Phys. 76(2) pp 1331 (1994), published International Patent Application No. PCT/US92/09367, and published International Patent Application No. PCT/US92/03504, all of which are incorporated herein by reference.

Suitable commercial nematic liquid crystals include, for example, E7, E44, E48, E31, E80, BL087, BL101, ZLI-3308, ZLI-3273, ZLI-5048-000, ZLI-5049-100, ZLI-5100-100, ZLI-5800-000, MLC-6041-100. TL202, TL203, TL204 and TL205 manufactured by E. Merck (Darmstadt, Germany). Although nematic liquid crystals having positive dielectric anisotropy, and especially cyanobiphenyls, are preferred, virtually any nematic liquid crystal known in the art, including those having negative dielectric anisotropy should be suitable for use in the invention. Other nematic materials may also be suitable for use in the present invention as would be appreciated by those skilled in the art.

The chiral dopant added to the nematic mixture to induce the helical twisting of the mesophase, thereby allowing reflection of visible light, can be of any useful structural class. The choice of dopant depends upon several characteristics including among others its chemical compatibility with the nematic host, helical twisting power, temperature sensitivity, and light fastness. Many chiral dopant classes are known in the art: for example, G. Gottarelli and G. Spada, *Mol. Cryst. Liq. Crys.*, 123, 377 (1985), G. Spada and G. Proni, *Enantiomer*, 3, 301 (1998) and references therein. Typical well known dopant classes include 1,1-binaphthol derivatives, isosorbide and similar isomannide esters as disclosed in U.S. Pat. No. 6,217,792, TADDOL derivatives as disclosed in U.S. Pat. No. 6,099,751, and the pending spiroindanes esters as disclosed in U.S. patent application Ser. No. 10/651,692 by T. Welter et al., filed Aug. 29, 2003,

titled "Chiral Compounds And Compositions Containing The Same," hereby incorporated by reference.

The pitch length of the liquid crystal materials may be adjusted based upon the following equation (1):

$$\lambda_{max}=n_{av}p_0$$

where λ_{max} is the peak reflection wavelength, that is, the wavelength at which reflectance is a maximum, n_{av} is the average index of refraction of the liquid crystal material, and p_0 is the natural pitch length of the chiral nematic helix. Definitions of chiral nematic helix and pitch length and methods of its measurement, are known to those skilled in the art such as can be found in the book, Blinov, L. M., Electro-optical and Magneto-Optical Properties of Liquid Crystals, John Wiley & Sons Ltd. 1983. The pitch length is modified by adjusting the concentration of the chiral material in the liquid crystal material. For most concentrations of chiral dopants, the pitch length induced by the dopant is inversely proportional to the concentration of the dopant. The proportionality constant is given by the following equation (2):

$$p_0=1/(HTP.c)$$

where c is the concentration of the chiral dopant and HTP is the proportionality constant.

For some applications, it is desired to have liquid crystal mixtures that exhibit a strong helical twist and thereby a short pitch length. For example in liquid crystalline mixtures that are used in selectively reflecting chiral nematic displays, the pitch has to be selected such that the maximum of the wavelength reflected by the chiral nematic helix is in the range of visible light. Other possible applications are polymer films with a chiral liquid crystalline phase for optical elements, such as chiral nematic broadband polarizers, filter arrays, or chiral liquid crystalline retardation films. Among these are active and passive optical elements or color filters and liquid crystal displays, for example STN, TN, AMD-TN, temperature compensation, polymer free or polymer stabilized chiral nematic texture (PFCT, PSCT) displays. Possible display industry applications include ultralight, flexible, and inexpensive displays for notebook and desktop computers, instrument panels, video game machines, videophones, mobile phones, hand held PCs, PDAs, e-books, camcorders, satellite navigation systems, store and supermarket pricing systems, highway signs, informational displays, smart cards, toys, and other electronic devices.

The liquid crystalline droplets or domains are typically dispersed in a continuous binder. In one embodiment, a chiral nematic liquid crystal composition may be dispersed in a continuous polymeric matrix. Such materials are referred to as "polymer dispersed liquid crystal" materials or "PDLC" materials. Suitable hydrophilic binders include both naturally occurring substances such as proteins, protein derivatives, cellulose derivatives (for example cellulose esters), gelatins and gelatin derivatives, polysaccaharides, casein, and the like, and synthetic water permeable colloids such as poly(vinyl lactams), acrylamide polymers, latex, poly(vinyl alcohol) and its derivatives, hydrolyzed polyvinyl acetates, polymers of alkyl and sulfoalkyl acrylates and methacrylates, polyamides, polyvinyl pyridine, acrylic acid polymers, maleic anhydride copolymers, polyalkylene oxide, methacrylamide copolymers, polyvinyl oxazolidinones, maleic acid copolymers, vinyl amine copolymers, methacrylic acid copolymers, acryloyloxyalkyl acrylate and methacrylates, vinyl imidazole copolymers, vinyl sulfide

copolymers, and homopolymer or copolymers containing styrene sulfonic acid. Gelatin is preferred.

Gelatin is derived from a material called collagen. Collagen has a high content of glycine and of the imino acids proline and hydroxyproline. It has a triple helix structure made up of three parallel chains. When collagen in water is heated above a certain temperature, it will denature to form gelatin. Concentrated gelatin solutions form rigid gels when cooled. This phenomenon is known as sol-gel transition or thermal gelation and is the result of secondary bonding, such as hydrogen bonding, between gelatin molecules in solution. It should be noted that this property is not limited to gelatin; for example, aqueous solutions of agar, a polysaccharide from seaweed, will also form rigid gels upon cooling. Partial renaturation of gelatin also occurs upon cooling. The latter refers to the formation of triple helix collagen-like structures. The structures do not form if gelatin is not chill set prior to drying. In other words, molecules of gelatin remain in a random coil configuration if the coating is dried at a temperature that is above the sol-gel transition temperature. The presence of helix structures may be detected by x-ray diffraction. Chill set gelatin containing molecules in a helix configuration has relatively low solubility in cold water and organic solvents compared to the random coil gelatin. This property enables chill set gelatin to be an effective barrier between the organic solvent in printed conductive inks and the light modulating material.

Useful "gelatins," as that term is used generically herein, include alkali treated gelatin (cattle bone or hide gelatin), acid treated gelatin (pigskin gelatin), fish skin gelatin and gelatin derivatives such as acetylated gelatin, and phthalated gelatin. Any type of gelatin may be used, provided the gelatin has sufficient molecular weight to allow the crosslinker to crosslink or the fixative to fix or set. Fish gelatins have lower imino acid content compared to mammalian gelatins. The sol-gel transition temperature or thermal gelation temperature or chill set temperature is lower if the imino acid content is smaller. For example, the chill set temperature of gelatins derived from deep water fish such as cod, haddock or pollock is significantly lower than that of cattle gelatin. Aqueous solutions of these gelatins remain fluid until about 10° C. whereas solutions of cattle gelatin will gel at room temperature. Other hydrophilic colloids that can be utilized alone or in combination with gelatin include dextran, gum arabic, zein, casein, pectin, collagen derivatives, collodion, agar-agar, arrowroot, albumin, and the like. Still other useful hydrophilic colloids are water soluble polyvinyl compounds such as polyvinyl alcohol, polyacrylamide, poly(vinylpyrrolidone), and the like. Useful liquid crystal to gelatin ratios should be between 6:1 and 0.5:1 liquid crystal to gelatin, preferably 3:1.

Other organic binders such as polyvinyl alcohol (PVA) or polyethylene oxide (PEO) can be used as minor components of the binder in addition to gelatin. Such compounds are preferably machine coatable on equipment associated with photographic films.

It is desirable that the binder has a low ionic content. The presence of ions in such a binder hinders the development of an electrical field across the dispersed liquid crystal material. Additionally, ions in the binder can migrate in the presence of an electrical field, chemically damaging the light modulating layer. The coating thickness, size of the liquid crystal domains, and concentration of the domains of liquid crystal materials are designed for optimum optical properties. Heretofore, the dispersion of liquid crystals is performed using shear mills or other mechanical separating means to form domains of liquid crystal within light modulating layer.

A conventional surfactant can be added to the emulsion to improve coating of the layer. Surfactants can be of conventional design, and are provided at a concentration that corresponds to the critical micelle concentration (CMC) of the solution. A preferred surfactant is Aerosol OT, commercially available from Cytec Industries, Inc.

In a preferred embodiment, the liquid crystal and gelatin emulsion are coated and dried to optimize the optical properties of the light modulating layer. In one embodiment, the layer is coated to provide a final coating containing a substantial monolayer of N*LC domains. The term "substantial monolayer" is defined by the Applicants to mean that, in a direction perpendicular to the plane of the display, there is no more than a single layer of domains sandwiched between the electrodes over 90% of the area of the display (or the imaging layer).

The amount of material needed for a monolayer can be determined by calculation based on individual domain size. Furthermore, improved viewing angle and broadband features may be obtained by appropriate choice of differently doped domains based on the geometry of the coated droplet and the Bragg reflection condition.

The addition of a bacteriostat prevents gelatin degradation during emulsion storage and during material operation. The gelatin concentration in the emulsion when coated is preferably between about 2 and 20 weight percent based on the weight of the emulsion. In the final emulsion, the liquid crystal material may be dispersed at 15% concentration in a 5% gelatin aqueous solution.

A crosslinking agent or hardener may be used to preserve the architecture of the close-packed monolayer of coated droplets after it has been formed by self-assembly. Other methods of fixing the architecture of the close-packed monolayer of domains may also be used, although crosslinking is preferred. The effects of the crosslinker may be characterized based on the reaction of certain amino acid residues in gelatin. For example, the amount of histadine is typically reduced from about 4 residues per 1000 to less than 2.5 residues per 1000 upon cross-linking. Also the amount of hydroxylysine is reduced from about 6.9 residues per 1000 to less than 5.1 residues per 1000. Many conventional hardeners are known to crosslink gelatin. Gelatin crosslinking agents (i.e., the hardener) are included in an amount of at least about 0.01 wt. % and preferably from about 0.1 to about 10 wt. % based on the weight of the solid dried gelatin material used (by dried gelatin it is meant substantially dry gelatin at ambient conditions as for example obtained from Eastman Gel Co., as compared to swollen gelatin), and more preferably in the amount of from about 1 to about 5 percent by weight. More than one gelatin crosslinking agent can be used if desired. Suitable hardeners may include inorganic, organic hardeners, such as aldehyde hardeners and olefinic hardeners. Inorganic hardeners include compounds such as aluminum salts, especially the sulfate, potassium and ammonium alums, ammonium zirconium carbonate, chromium salts such as chromium sulfate and chromium alum, and salts of titanium dioxide, and zirconium dioxide. Representative organic hardeners or gelatin crosslinking agents may include aldehyde and related compounds, pyridiniums, olefins, carbodiimides, and epoxides. Thus, suitable aldehyde hardeners include formaldehyde and compounds that contain two or more aldehyde functional groups such as glyoxal, gluteraldehyde and the like. Other preferred hardeners include compounds that contain blocked aldehyde functional groups such as aldehydes of the type tetrahydro-4-hydroxy-5-methyl-2(1H)-pyrimidinone polymers (Sequa SUNREZ® 700), polymers of the type having a glyoxal polyol reaction product consisting of 1 anhydroglucose unit: 2 glyoxal units (SEQUAREZ® 755 obtained from Sequa Chemicals, Inc.), DME-Melamine non-formaldehyde resins such as Sequa CPD3046-76 obtained from Sequa Chemicals Inc., and 2,3-dihydroxy-1,4-dioxane (DHD). Thus, hardeners that contain active olefinic functional groups include, for example, bis-(vinylsulfonyl)-methane (BVSM), bis-(vinylsulfonyl-methyl) ether (BVSME), 1,3,5-triacryloylhexahydro-s-triazine, and the like. In the context of the present invention, active olefinic compounds are defined as compounds having two or more olefinic bonds, especially unsubstituted vinyl groups, activated by adjacent electron withdrawing groups (The Theory of the Photographic Process, 4th Edition, T. H. James, 1977, Macmillan Publishing Co., page 82). Other examples of hardening agents can be found in standard references such as The Theory of the Photographic Process, T. H. James, Macmillan Publishing Co., Inc. (New York 1977) or in Research Disclosure, September 1996, Vol. 389, Part IIB (Hardeners) or in Research Disclosure, September 1994, Vol. 365, Item 36544, Part IIB (Hardeners). Research Disclosure is published by Kenneth Mason Publications, Ltd., Dudley House, 12 North St., Emsworth, Hampshire P010 7DQ, England. Olefinic hardeners are most preferred, as disclosed in U.S. Pat. Nos. 3,689,274, 2,994,611, 3,642,486, 3,490,911, 3,635,718, 3,640,720, 2,992,109, 3,232,763, and 3,360,372.

Among hardeners of the active olefin type, a preferred class of hardeners particularly are compounds comprising two or more vinyl sulfonyl groups. These compounds are hereinafter referred to as "vinyl sulfones". Compounds of this type are described in numerous patents including, for example, U.S. Pat. Nos. 3,490,911, 3,642,486, 3,841,872 and 4,171,976. Vinyl sulfone hardeners are believed to be effective as hardeners as a result of their ability to crosslink polymers making up the colloid.

The liquid crystalline droplets or domains may be formed by any method, known to those of skill in the art, which will allow control of the domain size. For example, Doane et al. (*Applied Physics Letters*, 48, 269 (1986)) disclose a PDLC comprising approximately 0.4 μm droplets of nematic liquid crystal 5CB in a polymer binder. A phase separation method is used for preparing the PDLC.

A solution containing monomer and liquid crystal is filled in a display cell and the material is then polymerized. Upon polymerization the liquid crystal becomes immiscible and nucleates to form droplets. West et al. (Applied Physics Letters 63, 1471 (1993)) disclose a PDLC comprising a chiral nematic mixture in a polymer binder. Once again a phase separation method is used for preparing the PDLC. The liquid crystal material and polymer (a hydroxy functionalized polymethylmethacrylate) along with a crosslinker for the polymer are dissolved in a common organic solvent toluene and coated on an indium tin oxide (ITO) substrate. A dispersion of the liquid crystal material in the polymer binder is formed upon evaporation of toluene at high temperature. The phase separation methods of Doane et al. and West et al. require the use of organic solvents that may be objectionable in certain manufacturing environments.

In a preferred embodiment, a method referred to as "limited coalescence" is used to form uniformly sized emulsions of liquid crystalline material. For example, the liquid crystal material can be homogenized in the presence of finely divided silica, a coalescence limiting material, such as LUDOX® from DuPont Corporation. A promoter material can be added to the aqueous bath to drive the colloidal particles to the liquid-liquid interface. In a preferred embodiment, a copolymer of adipic acid and 2-(methylamino)

ethanol can be used as the promoting agent in the water bath. The liquid crystal material can be dispersed using ultrasound to create liquid crystal domains below 1 micron in size. When the ultrasound energy is removed, the liquid crystal material coalesces into domains of uniform size. The limited coalescence process is described more fully by Whitesides and Ross (J. Colloid Interface Sci. 169, 48 (1995)), by Giermanska-Kahn, Schmitt, Binks and Leal-Calderon (Langmuir, 18, 2515 (2002)), and U.S. Pat. No. 6,556,262, all incorporated herein by reference.

The distribution of droplet sizes is such that the coefficient of variation (cv) defined as the standard deviation of the distribution divided by the arithmetic mean is less than 0.25, preferably less than 0.2 and most preferably less than 0.15. The limited coalescent materials can be coated using a photographic emulsion coating machine onto sheets of polyester having an ITO coating with a sheet conductivity of 300 ohms per square. The coating can be dried to provide a polymerically dispersed cholesteric coating. By using limited coalescence, there are few, if any, parasitic smaller domains (having undesirable electro-optical properties) within the dried coatings.

The size ranges of domains in the dried coating are varied as the mixture dries and the domains flatten. In one embodiment, the resulting domains are flattened by the drying process and have on average a thickness substantially less than their length. The flattening of the domains can be achieved by proper formulation and sufficiently rapid drying of the coating.

Preferably, the domains are flattened spheres and have on average a thickness substantially less than their length, preferably at least 50% less. More preferably, the domains on average have a thickness (depth) to length ratio of 1:2 to 1:6. The flattening of the domains can be achieved by proper formulation and sufficiently rapid drying of the coating. The domains preferably have an average diameter of 2 to 30 microns. The imaging layer preferably has a thickness of 10 to 150 microns when first coated and 2 to 20 microns when dried. Most preferably the imaging layer or light modulating layer has a thickness between 2 to 6 microns, particularly if the light modulating material is a chiral nematic liquid crystal.

The flattened domains of liquid crystal material can be defined as having a major axis and a minor axis. In a preferred embodiment of a display or display sheet, the major axis is larger in size than the cell (or imaging layer) thickness for a majority of the domains. Such a dimensional relationship is shown in U.S. Pat. No. 6,061,107, hereby incorporated by reference in its entirety.

In U.S. Pat. No. 3,600,060, incorporated herein by reference, the domains of the dried light modulating material had particle size varying in diameter by a ratio of 10:1. This creates large domains and smaller parasitic domains. Parasitic domains have reduced characteristics when compared with optimized larger domains. The reduced characteristics include reduced brightness and if the parasitic domains are small enough diminished bistability of the cholesteric liquid crystal.

The dispersed domains have an average diameter of 2 to 30 microns, preferably 5 to 15 microns. The domains are dispersed in an aqueous suspension. The size ranges for the dried coating are varied as the mixture dries and the domains flatten.

By varying the amount of silica and copolymer relative to the liquid crystalline material, uniform domain size emulsions of the desired average diameter (by microscopy), can be produced. This process produces domains of a selected average diameter.

The resulting domains are flattened by the drying process and have on average a thickness substantially less than their length, preferably at least 50% less. More preferably, the domains on average have a thickness (depth) to length ratio of 1:2 to 1:10.

For optimal performance one requires a monolayer of coated droplets having a close-packed structure of uniform thickness. Calculations by Yang and Mi (J. Phys. D: Appl. Phys. Vol. 33, page 672, 2000) have shown that for a chiral nematic liquid crystalline material of a given handedness, maximum reflectance is obtained if the thickness of the chiral nematic liquid crystal material between the electrodes is about ten times the pitch of the chiral nematic helix. For a green reflecting chiral nematic liquid crystal material with λ_{max} of 550 nm and n_{av} of 1.6 the pitch is 344 nm. Therefore, maximum reflectance is obtained for a 3.4 μm thick layer of this material. For chiral nematic liquid crystal materials that reflect in the red and near infrared portions of the spectrum, the pitch and therefore the thickness of the coated layer needed for maximum reflectance will be somewhat higher but even in these cases a thickness of about 5 μm is sufficient, if the refractive index is close to 1.6. In other words, increasing the thickness of the layer beyond this does not provide an increase in reflectance.

It is also well documented that the switching voltage increases linearly with thickness. Since it is desirable to have the lowest possible switching voltage, a uniform thickness of about 5 μm is most preferred for the coated layer of droplets, provided the droplets have a close-packed structure. Under certain conditions, monodisperse droplets of the light modulating material will spontaneously self-assemble on a surface into a hexagonal close-packed (HCP) structure. The process has been described in detail by Denkov et al. (Nature, vol. 361, p. 26, 1993). When an aqueous suspension of droplets is spread on a surface, the droplets initially assume a random, disordered or uncorrelated distribution. However, as a function of drying, when the level of water reaches the top of the droplets, there is a strong attractive force known as the capillary force that drives the droplets into a close-packed ordered or correlated structure. The attractive energy of the capillary force is much greater than the thermal energy. However, it is important that lateral movement of droplets is not impeded by a strong attraction to the surface or by an increase in viscosity of the medium in which they are suspended. The latter would happen if the binder is gelatin and the coated layer of droplets is chill set prior to drying.

The formation of a close-packed structure in two dimensions, starting from a random distribution of droplets, is sometimes referred to as two-dimensional crystallization and should have a monodisperse population of droplets or a population of droplets having low polydispersity (Kumacheva et al. Physical Review Letters vol. 91, page 1283010-1, 2003). A population of droplets of light modulating material having sufficiently low polydispersity to create a close-packed structure may be achieved by the limited coalescence process. The close-packed structure is readily observable under an optical microscope. Furthermore, the close-packed structure has a repeat pattern or periodicity wherein the repeat distance is of the order of the wavelength of visible light. A coating having such a pattern exhibits Fraunhofer diffraction when placed before a source of visible light such as a visible light laser. The phenomenon of

Fraunhofer diffraction is described more fully by Lisensky et al. Journal of Chemical Education, vol. 68, February 1991.

For perfectly monodisperse droplets (cv less than 0.1), a hexagonal close-packed (HCP) structure is obtained. The diffraction pattern for such a structure is in the form of spots. If there is a minor level of polydispersity (cv between 0.1 and 0.2), the diffraction pattern of the close-packed structure is in the form of a single ring or a set of concentric rings.

The close-packed monolayer structure of coated droplets may be preserved by fixing or crosslinking the binder. This allows a second aqueous layer to be coated above the layer containing the light modulating material without disturbing the close-packed organization. In a preferred embodiment, the second layer functions as a protective overcoat for the light modulating material.

One embodiment of the present invention also may provide a broad band cholesteric reflection, which allows for black and white operation of polymer dispersed cholesteric LC displays. This is achieved by doping the LC with a UV curable polymer which distributes the helical axes of the LC to allow for reflection at many wavelengths. The high contrast reflective display of this embodiment utilizes at least one electronically modulated imaging layer comprising a chiral nematic liquid crystal light modulating material having positive dielectric anisotropy and a pitch length effective to reflect light of approximately 600 nm and a UV curable polymer. The chiral nematic liquid crystal light modulating material and the UV curable polymer cooperate to form focal conic textures and twisted planar textures that are stable in the absence of a field. The twisted planar texture is light reflecting and appears substantially white, while the focal conic texture is weakly scattering. This weakly scattering focal conic texture may appear as the same color as surrounding layers, if the surrounding layers are colored. For example, the weakly scattering focal conic texture may appear as the same color as the rearmost surface of the display or a color contrast layer located behind the rearmost surface, wherein said focal conic texture appears substantially the same color as a color contrast layer located to the rear of the LC layer. It should be noted that "rearmost" is determined as being further away from the point of viewing of the display, typically, further away from the transparent support. In a black and white display, the rearmost layer or color contrast layer is black.

The material used to form the UV curable polymer networks is soluble with the chiral nematic liquid crystal and phase separates upon polymerization to form phase separated polymer domains. Suitable UV curable polymer materials may be selected from UV (ultra violet) curable, thermoplastic and thermosetting polymers, including polymers formed from monomers having at least two polymerizable double bonds so as to be cross-linkable, polymethylmethacrylates, bisacrylates, hydroxyfunctionalized polymethacrylates and epoxy systems to name a few. The amount of UV curable polymer to be used depends upon the UV curable polymer. Useful results have been obtained with UV curable polymer contents ranging from about 1.5 to about 40% depending upon the UV curable polymer. For black and white display units, it has been found that optimal results are obtained when the UV curable polymer content of the liquid crystal material is about 3%.

A preferred embodiment of the display device shown in FIG. **6** comprises a clear flexible support **101** with a clear conducting layer **102**. The imaging layer or light modulating layer (layer 1) contains a close-packed monolayer of droplets of the light modulating material **104** along with crosslinked binder **103** in a random coil configuration. A protective overcoat **105** is composed of polymer in a helix configuration. The second electrode **106** comprises screen printed carbon conductive ink.

A second preferred embodiment of the display device, shown in FIG. 7, comprises a clear flexible support **101** with a clear conducting layer **102**. The imaging layer or light modulating layer (layer 1) contains a close-packed monolayer of droplets of the light modulating material **104** along with crosslinked binder **103** in a random coil configuration. A protective overcoat **107** is composed of polymer in a helix configuration and dispersed carbon black for improved contrast. The second electrode **108** comprises screen printed silver conductive ink.

In addition to binder and hardener, liquid crystal layers may also contain a small amount of light absorbing colorant, preferably an absorber dye. It is preferred that an absorbing dye is used to selectively absorb back scattered light from the focal conic state at the lowest wavelengths in the visible part of the spectrum. Further, the colorant selectively absorbs similarly scattered light from the planar state, while only minimally absorbing the main body of reflected light. The colorants may include both dyes and pigments. The colorant may absorb light components, which may cause turbidity of color in the color display performed by selective reflection of the liquid crystal or may cause lowering of a transparency in the transparent state of the liquid crystal, and therefore can improve the display quality. Two or more of the components in the liquid crystal display may contain a coloring agent. For example, both the polymer and the liquid crystal may contain the coloring agent. Preferably, a colorant is selected, which absorbs rays in a range of shorter wavelengths than the selective reflection wavelength of the liquid crystal.

Any amount of colorant may be used, provided that addition of the colorant does not remarkably impair the switching characteristics of the liquid crystal material for display. In addition, if the polymeric binder is formed by polymerization, the addition does not inhibit the polymerization. An exemplary amount of colorant is from at least 0.1 weight % to 5 weight % of the liquid crystal material.

In a preferred embodiment, the colorants, preferably absorber dyes, are incorporated directly in the chiral nematic liquid crystal materials. Any colorants that are miscible with the cholesteric liquid crystal materials are useful for this purpose. Most preferred are colorants that are readily soluble in toluene. By readily soluble is meant a solubility greater than 1 gram per liter, more preferably greater than 10 grams per liter and most preferably greater than 100 grams per liter. Toluene soluble dyes most compatible with the cholesteric liquid crystal materials are anthraquinone dyes such as Sandoplast Blue 2B from Clariant Corporation, phthalocyanine dyes such as Savinyl Blue GLS from Clariant Corporation or Neozapon Blue 807 from BASF Corporation, methine dyes such as Sandoplast Yellow 3G from Clariant Corporation or metal complex dyes such as Neozapon Yellow 157, Neozapon Orange 251, Neozapon Green 975, Neozapon Blue 807 or Neozapon Red 365 from BASF Corporation. Other colorants are Neopen Blue 808, Neopen Yellow 075, Sudan Orange 220 or Sudan Blue 670 from BASF Corporation. Other types of colorants may include various kinds of dyestuff such as dyestuff for resin coloring and dichromatic dyestuff for liquid crystal display. The dyestuff for resin coloring may be SPR RED1 (manufactured by Mitsui Toatsu Senryo Co., Ltd.). The dichromatic dyestuff for liquid crystal is specifically SI-424 or M-483 (both manufactured by Mitsui Toatsu Senryo Co., Ltd.).

Another aspect of the present invention relates to a display sheet comprising a substrate, an electrically conductive layer formed over the substrate, and a liquid crystal containing imaging layer comprising a chiral nematic material formed by the above described methods disposed over the electrically conductive layer.

As used herein, the phrase a "liquid crystal display" (LCD) is a type of flat panel display used in various electronic devices. At a minimum, a LCD comprises a substrate, at least one conductive layer and a liquid crystal layer. LCDs may also comprise two sheets of polarizing material with a liquid crystal solution between the polarizing sheets. The sheets of polarizing material may comprise a substrate of glass or transparent plastic. The LCD may also include functional layers. In one embodiment of a LCD, a transparent, multilayer flexible support is coated with a first conductive layer, which may be patterned, onto which is coated the light modulating liquid crystal layer. A second conductive layer is applied and overcoated with a dielectric layer to which dielectric conductive row contacts are attached, including via holes that permit interconnection between conductive layers and the dielectric conductive row contacts. An optional nanopigmented functional layer may be applied between the liquid crystal layer and the second conductive layer.

The liquid crystal (LC) is used as an optical switch. The substrates are usually manufactured with transparent, conductive electrodes, in which electrical "driving" signals are coupled. The driving signals induce an electric field which can cause a phase change or state change in the liquid crystal material, thus exhibiting different light reflecting characteristics according to its phase and/or state.

Cholesteric liquid crystals are bistable at zero field and drive schemes may be designed based on their response to voltage pulses. A typical response of a bistable cholesteric or chiral nematic liquid crystal material to voltage pulses is shown in FIG. **8**. The horizontal axis represents the amplitude of the addressing voltage pulse and the vertical axis represents the reflectance measured after the liquid crystal relaxes to the stable state following application of the voltage pulse. The solid line is the response, when the material is initially in the planar state or texture, and the dashed line is the response, when the material is initially in the focal conic texture. In the conventional drive scheme for bistable cholesteric displays, the displays are addressed row by row. With reference to FIG. **8**, if the row voltage VR is set at $VR=(V3+V4)/2$, then the column voltage VC has to be within the range $V4-VR<VC<V1$ for all columns in order to derive maximum contrast without cross-talk in a matrix or multiplexed display. By without cross-talk, it is meant that the portion of the image that has already been written on a multi-row display device will not be altered when a new row is selected and addressed. From the above relationships, it follows that for maximum contrast without cross-talk, $(V4-V3)/2<V1$. If we define a quantity $Vqm=2V1/(V4-V3)$, it is clearly desirable that Vqm is greater than or at least equal to 1.

The displays may employ any suitable driving schemes and electronics known to those skilled in the art, including the following, all of which are incorporated herein by reference in their entireties: Doane, J. W., Yang, D. K., *Front-lit Flat Panel Display from Polymer Stabilized Cholesteric Textures*, Japan Display 92, Hiroshima October 1992; Yang, D. K. and Doane, J. W., *Cholesteric Liquid Crystal/Polymer Gel Dispersion: Reflective Display Application*, SID Technical Paper Digest, Vol XXIII, May 1992, p. 759, et sea.; U.S. patent application Ser. No. 08/390,068,

filed Feb. 17, 1995, entitled "Dynamic Drive Method and Apparatus for a Bistable Liquid Crystal Display" and U.S. Pat. No. 5,453,863.

A typical display in its simplest form comprises a sheet supporting a conventional polymer dispersed electrically modulated material. The sheet includes a substrate. Substrate can be made of a polymeric material, such as Kodak Estar film base formed of polyester plastic, and have a thickness of between 20 and 200 microns. For example, substrate can be a 80 micron thick sheet of transparent polyester. Other polymers, such as transparent polycarbonate, can also be used. Alternatively, substrate can be thin, transparent glass.

A first conductor is formed over substrate. First conductor can be a transparent, electrically conductive layer of tin-oxide or indium-tin-oxide (ITO), with ITO being the preferred material. Typically, first conductor is sputtered onto the substrate to a resistance of less than 250 ohms per square. Alternatively, first conductor can be an opaque electrical conductor formed of metal such as copper, aluminum or nickel. If first conductor is an opaque metal, the metal can be a metal oxide to create a light absorbing first conductor. A second conductor may be applied to the surface of light modulating imaging layer. Second conductor should have sufficient conductivity to carry a field across light modulating imaging layer. Second conductor can be formed in a vacuum environment using materials such as aluminum, tin, silver, platinum, carbon, tungsten, molybdenum, or indium.

In a preferred embodiment of the invention, the display device or display sheet has simply a single imaging layer of liquid crystal material along a line perpendicular to the face of the display, preferably a single layer coated on a flexible substrate. Such as structure, as compared to vertically stacked imaging layers each between opposing substrates, is especially advantageous for monochrome shelf labels and the like. Structures having stacked imaging layers, however, are optional for providing additional advantages in some case.

In a typical matrix-addressable light emitting display device, numerous light emitting devices are formed on a single substrate and arranged in groups in a regular grid pattern. Activation may be by rows and columns, or in an active matrix with individual cathode and anode paths. OLEDs are often manufactured by first depositing a transparent electrode on the substrate, and patterning the same into electrode portions. The organic layer(s) is then deposited over the transparent electrode. A metallic electrode can be formed over the electrode layers. For example, in U.S. Pat. No. 5,703,436 to Forrest et al., incorporated herein by reference, transparent indium tin oxide (ITO) is used as the Hole injecting electrode, and a Mg—Ag-ITO electrode layer is used for electron injection.

The flexible plastic substrate can be any flexible self-supporting plastic film that supports the thin conductive metallic film. "Plastic" means a high polymer, usually made from polymeric synthetic resins, which may be combined with other ingredients, such as curatives, fillers, reinforcing agents, colorants, and plasticizers. Plastic includes thermoplastic materials and thermosetting materials.

The flexible plastic film must have sufficient thickness and mechanical integrity so as to be self-supporting, yet should not be so thick as to be rigid. Typically, the flexible plastic substrate is the thickest layer of the composite film in thickness. Consequently, the substrate determines to a large extent the mechanical and thermal stability of the fully structured composite film.

Another significant characteristic of the flexible plastic substrate material is its glass transition temperature (Tg). Tg is defined as the glass transition temperature at which plastic material will change from the glassy state to the rubbery state. It may comprise a range before the material may actually flow. Suitable materials for the flexible plastic substrate include thermoplastics of a relatively low glass transition temperature, for example up to 150° C., as well as materials of a higher glass transition temperature, for example, above 150° C. The choice of material for the flexible plastic substrate would depend on factors such as manufacturing process conditions, such as deposition temperature, and annealing temperature, as well as post manufacturing conditions such as in a process line of a displays manufacturer. Certain of the plastic substrates discussed below can withstand higher processing temperatures of up to at least about 200° C., some up to 300-350° C., without damage.

Typically, the flexible plastic substrate is polyethylene terephthalate (PET), polyethylene naphthalate (PEN), polyethersulfone (PES), polycarbonate (PC), polysulfone, a phenolic resin, an epoxy resin, polyester, polyimide, polyetherester, polyetheramide, cellulose acetate, aliphatic polyurethanes, polyacrylonitrile, polytetrafluoroethylenes, polyvinylidene fluorides, poly(methyl(x-methacrylates), an aliphatic or cyclic polyolefin, polyarylate (PAR), polyetherimide (PEI), polyethersulphone (PES), polyimide (PI), Teflon poly(perfluoro-alboxy) fluoropolymer (PFA), poly (ether ether ketone) (PEEK), poly(ether ketone) (PEK), poly(ethylene tetrafluoroethylene) fluoropolymer (PETFE), and poly(methyl methacrylate) and various acrylate/methacrylate copolymers (PMMA). Aliphatic polyolefins may include high density polyethylene (HDPE), low density polyethylene (LDPE), and polypropylene, including oriented polypropylene (OPP). Cyclic polyolefins may include poly(bis(cyclopentadiene)). A preferred flexible plastic substrate is a cyclic polyolefin or a polyester. Various cyclic polyolefins are suitable for the flexible plastic substrate. Examples include Arton® made by Japan Synthetic Rubber Co., Tokyo, Japan, Zeanor T made by Zeon Chemicals L.P., Tokyo Japan, and Topas® made by Celanese A. G., Kronberg Germany. Arton is a poly(bis(cyclopentadiene)) condensate that is a film of a polymer. Alternatively, the flexible plastic substrate can be a polyester. A preferred polyester is an aromatic polyester such as Arylite. Although various examples of plastic substrates are set forth above, it should be appreciated that the substrate can also be formed from other materials such as glass and quartz.

The flexible plastic substrate can be reinforced with a hard coating. Typically, the hard coating is an acrylic coating. Such a hard coating typically has a thickness of from 1 to 15 microns, preferably from 2 to 4 microns and can be provided by free radical polymerization, initiated either thermally or by ultraviolet radiation, of an appropriate polymerizable material. Depending on the substrate, different hard coatings can be used. When the substrate is polyester or Arton, a particularly preferred hard coating is the coating known as "Lintec". Lintec contains UV cured polyester acrylate and colloidal silica. When deposited on Arton, it has a surface composition of 35 atom % C, 45 atom % 0, and 20 atom % Si, excluding hydrogen. Another particularly preferred hard coating is the acrylic coating sold under the trademark "Terrapin" by Tekra Corporation, New Berlin, Wis.

The LCD contains at least one conductive layer, which typically is comprised of a primary metal oxide. This conductive layer may comprise other metal oxides such as indium oxide, titanium dioxide, cadmium oxide, gallium indium oxide, niobium pentoxide and tin dioxide. See, Int. Publ. No. WO 99/36261 by Polaroid Corporation. In addition to the primary oxide such as ITO, the at least one conductive layer can also comprise a secondary metal oxide such as an oxide of cerium, titanium, zirconium, hafnium and/or tantalum. See, U.S. Pat. No. 5,667,853 to Fukuyoshi et al. (Toppan Printing Co.) Other transparent conductive oxides include, but are not limited to ZnO_2, Zn_2SnO_4, Cd_2SnO_4, $Zn_2In_2O_5$, $MgIn_2O_4$, Ga_2O_3—In_2O_3, or TaO_3. The conductive layer may be formed, for example, by a low temperature sputtering technique or by a direct current sputtering technique, such as DC sputtering or RF-DC sputtering, depending upon the material or materials of the underlying layer. The conductive layer may be a transparent, electrically conductive layer of tin oxide or indium tin oxide (ITO), or polythiophene (PDOT). Typically, the conductive layer is sputtered onto the substrate to a resistance of less than 250 ohms per square. Alternatively, conductive layer may be an opaque electrical conductor formed of metal such as copper, aluminum or nickel. If the conductive layer is an opaque metal, the metal can be a metal oxide to create a light absorbing conductive layer.

The material is coated over patterned ITO first conductors to provide a polymer dispersed cholesteric coating having a dried thickness of less than 50 microns, preferably less than 25 microns, more preferably less than 15 microns, most preferably less than about 10 microns.

Indium tin oxide (ITO) is the preferred conductive material, as it is a cost effective conductor with good environmental stability, up to 90% transmission, and down to 20 ohms per square resistivity. An exemplary preferred ITO layer has a % T greater than or equal to 80% in the visible region of light, that is, from greater than 400 nm to 700 nm, so that the film will be useful for display applications. In a preferred embodiment, the conductive layer comprises a layer of low temperature ITO, which is polycrystalline. The ITO layer is preferably 10-120 nm in thickness, or 50-100 nm thick to achieve a resistivity of 20-60 ohms/square on plastic. An exemplary preferred ITO layer is 60-80 nm thick.

The conductive layer is preferably patterned. The conductive layer is preferably patterned into a plurality of electrodes. The patterned electrodes may be used to form a LCD device. In another embodiment, two conductive substrates are positioned facing each other and cholesteric liquid crystals are positioned there between to form a device. The patterned ITO conductive layer may have a variety of dimensions. Exemplary dimensions may include line widths of 10 microns, distances between lines, that is, electrode widths, of 200 microns, depth of cut, that is, thickness of ITO conductor, of 100 nanometers. ITO thicknesses on the order of 60, 70, and greater than 100 nanometers are also possible.

The display may also contain a second conductive layer applied to the surface of the light modulating layer. The second conductive layer desirably has sufficient conductivity to carry a field across the light modulating layer. The second conductive layer may be formed in a vacuum environment using materials such as aluminum, tin, silver, platinum, carbon, tungsten, molybdenum, or indium. Oxides of these metals can be used to darken patternable conductive layers. The metal material can be excited by energy from resistance heating, cathodic arc, electron beam, sputtering or magnetron excitation. The second conductive layer may comprise coatings of tin oxide or indium tin oxide, resulting in the layer being transparent. Alternatively, second conductive layer may be printed conductive ink.

For higher conductivities, the second conductive layer may comprise a silver based layer which contains silver only or silver containing a different element such as aluminum (Al), copper (Cu), nickel (Ni), cadmium (Cd), gold (Au), zinc (Zn), magnesium (Mg), tin (Sn), indium (In), tantalum (Ta), titanium (Ti), zirconium (Zr), cerium (Ce), silicon (Si), lead (Pb) or palladium (Pd). In a preferred embodiment, the conductive layer comprises at least one of gold, silver and a gold/silver alloy, for example, a layer of silver coated on one or both sides with a thinner layer of gold. See, Int. Publ. No. WO 99/36261 by Polaroid Corporation. In another embodiment, the conductive layer may comprise a layer of silver alloy, for example, a layer of silver coated on one or both sides with a layer of indium cerium oxide (InCeO). See U.S. Pat. No. 5,667,853, incorporated herein in by reference.

The second conductive layer may be patterned irradiating the multilayered conductor/substrate structure with ultraviolet radiation so that portions of the conductive layer are ablated therefrom. It is also known to employ an infrared (IR) fiber laser for patterning a metallic conductive layer overlying a plastic film, directly ablating the conductive layer by scanning a pattern over the conductor/film structure. See: Int. Publ. No. WO 99/36261 and "42.2: A New Conductor Structure for Plastic LCD Applications Utilizing 'All Dry' Digital Laser Patterning," 1998 SID International Symposium Digest of Technical Papers, Anaheim, Calif., May 17-22, 1998, no. VOL. 29, May 17, 1998, pages 1099-1101, both incorporated herein by reference.

In a preferred embodiment, second conductors are printed conductive ink such as ELECTRODAG 423SS screen printable electrical conductive material from Acheson Corporation. Such printed materials are finely divided graphite particles in a thermoplastic resin. The second conductors are formed using printed inks to reduce display cost. The use of a flexible support for substrate layer, laser etched first conductors, machine coating polymer dispersed cholesteric layer, and printing second conductors permit the fabrication of very low cost memory displays. Small displays formed using these methods can be used as electronically rewritable transaction cards for inexpensive, limited rewrite applications.

A light absorbing second conductor may be positioned on the side opposing the incident light. In the fully evolved focal conic state the cholesteric liquid crystal is transparent, passing incident light, which is absorbed by second conductor to provide a black image. Progressive evolution to the focal conic state causes a viewer to see an initial bright reflected light that transitions to black as the cholesteric material changes from planar state to a fully evolved focal conic state. The transition to the light transmitting state is progressive, and varying the low voltage time permits variable levels of reflection. These variable levels can be mapped out to corresponding gray levels, and when the field is removed, light modulating layer maintains a given optical state indefinitely. The states are more fully discussed in U.S. Pat. No. 5,437,811.

In addition to a second conductive layer, other means may be used to produce a field capable of switching the state of the liquid crystal layer as described in, for example, U.S. Pat Appl. Nos. 20010008582 A1, 20030227441 A1, 20010006389 A1, and U.S. Pat. Nos. 6,424,387, 6,269,225, and 6,104,448, all incorporated herein by reference.

The LCD may also comprise at least one "functional layer" between the conductive layer and the substrate. The functional layer may comprise a protective layer or a barrier layer. The protective layer useful in the practice of the invention can be applied in any of a number of well known

techniques, such as dip coating, rod coating, blade coating, air knife coating, gravure coating and reverse roll coating, extrusion coating, slide coating, curtain coating, and the like. The liquid crystal particles and the binder are preferably mixed together in a liquid medium to form a coating composition. The liquid medium may be a medium such as water or other aqueous solutions in which the hydrophilic colloid are dispersed with or without the presence of surfactants. A preferred barrier layer may acts as a gas barrier or a moisture barrier and may comprise SiOx, AlOx or ITO. The protective layer, for example, an acrylic hard coat, functions to prevent laser light from penetrating to functional layers between the protective layer and the substrate, thereby protecting both the barrier layer and the substrate. The functional layer may also serve as an adhesion promoter of the conductive layer to the substrate.

In another embodiment, the polymeric support may further comprise an antistatic layer to manage unwanted charge build up on the sheet or web during roll conveyance or sheet finishing. In another embodiment of this invention, the antistatic layer has a surface resistivity of between 10^5 to 10^{12} ohms. Above 10^{12}, the antistatic layer typically does not provide sufficient conduction of charge to prevent charge accumulation to the point of preventing fog in photographic systems or from unwanted point switching in liquid crystal displays. While layers greater than 10^5 will prevent charge buildup, most antistatic materials are inherently not that conductive and in those materials that are more conductive than 10^5, there is usually some color associated with them that will reduce the overall transmission properties of the display. The antistatic layer is separate from the highly conductive layer of ITO and provides the best static control when it is on the opposite side of the web substrate from that of the ITO layer. This may include the web substrate itself.

Another type of functional layer may be a color contrast layer. Color contrast layers may be radiation reflective layers or radiation absorbing layers. In some cases, the rearmost substrate of each display may preferably be a color contrast layer. The rearmost substrate may also preferably be painted black. The color contrast layer may also be other colors. In another embodiment, the dark layer comprises milled nonconductive pigments. The materials are milled below 1 micron to form "nanopigments". In a preferred embodiment, the dark layer absorbs all wavelengths of light across the visible light spectrum, that is from 400 nanometers to 700 nanometers wavelength. The dark layer may also contain a set or multiple pigment dispersions. Suitable pigments used in the color contrast layer may be any colored materials, which are practically insoluble in the medium in which they are incorporated. Suitable pigments include those described in Industrial Organic Pigments: Production, Properties, Applications by W. Herbst and K. Hunger, 1993, Wiley Publishers. These include, but are not limited to, Azo Pigments such as monoazo yellow and orange, diazo, naphthol, naphthol reds, azo lakes, benzimidazolone, diazo condensation, metal complex, isoindolinone and isoindolinic, polycyclic pigments such as phthalocyanine, quinacridone, perylene, perinone, diketopyrrolo-pyrrole, and thioindigo, and anthriquinone pigments such as anthrapyrimidine.

The functional layer may also comprise a dielectric material. A dielectric layer, for purposes of the present invention, is a layer that is not conductive or blocks the flow of electricity. This dielectric material may include a UV curable, thermoplastic, screen printable material, such as Electrodag 25208 dielectric coating from Acheson Corporation. The dielectric material forms a dielectric layer. This layer may include openings to define image areas, which are

coincident with the openings. Since the image is viewed through a transparent substrate, the indicia are mirror imaged. The dielectric material may form an adhesive layer to subsequently bond a second electrode to the light modulating layer.

The liquid crystal containing composition of the invention can be applied by any of a number of well known techniques, such as dip coating, rod coating, blade coating, air knife coating, slide (or bead) coating, curtain coating, and the like.

After coating, the layer is generally dried by simple evaporation, which may be accelerated by known techniques such as convection heating. Known coating and drying methods are described in further detail in Research Disclosure No. 308119, Published December 1989, pages 1007 to 1008. The coating is maintained above the chill set temperature or sol-gel transition temperature of gelatin during drying of the imaging layer or light modulating layer to permit self-assembly of the droplets into a close-packed monolayer.

A coated sheet can be formed using inexpensive, efficient layering methods. A single large volume of sheet material can be coated and formed into various types of smaller sheets for use in display devices such as transaction cards, shelf labels, large format signage, and the like. Displays in the form of sheets in accordance with the present invention are inexpensive, simple, and fabricated using low cost processes.

In the preferred embodiment, the imaging layer or light modulating layer is first applied and maintained above the chill set temperature or sol-gel transition temperature of gelatin. After drying, the binder in this layer is allowed to crosslink to preserve the close-packed monolayer distribution of coated droplets. A second aqueous layer containing gelatin is then applied. The coating is chill set prior to drying of the second layer in order to allow the gelatin molecules in the second layer to adopt a helix structure In a preferred commercial embodiment, the substrate to be coated is in the form of a moving web. After completing the manufacture of a coated liquid crystal sheet material between spaced electrodes, the sheet material can be cut into a plurality of smaller, individual areas for use in various display or other applications.

A close-packed monolayer of uniform thickness may provide enhanced performance with respect to surface roughness. In conventional liquid crystal coatings containing non-uniform droplets or capsules, the root mean square (RMS) surface roughness has been measured at about 6 microns. This is a very high value of surface roughness that would result in irregular or incomplete curing if a UV curable screen printed conducive ink is used as the second electrode. The irregular curing will result in increased switching voltages. Furthermore, a surface roughness of this magnitude will also result in significant non-uniformity of switching voltage across the area of the display since the switching voltage is directly related to the thickness of the coated layer. The self-assembled droplets or domains in the present close-packed monolayer demonstrates a RMS surface roughness of less than 1.5 microns, more preferably less than 1.0 microns and most preferably less than 0.5 microns.

The following examples are provided to illustrate the invention.

EXAMPLE 1

This example illustrates the close-packed ordered monolayer structure obtained according to the invention compared to the random structure of a control coating.

Chiral nematic liquid crystal (CLC) compositions with center wavelengths of reflection (CWR) at 540 nm and 590 nm were prepared by adding the appropriate amount of a high twist chiral dopant to the nematic host mixture BL087 obtained from Merck, Darmstadt, Germany. The CLC composition with CWR at 590 nm also contained 0.2% weight/weight (w/w) of the blue absorbing dye Neopen Yellow 057 from BASF Corporation.

Method I (Invention)

A dispersion of the CLC composition with CWR at 590 nm was prepared as follows. To 241 grams of distilled water was added 3.6 grams of Ludox™ colloidal silica suspension and 7.4 grams of a 10% w/w aqueous solution of a copolymer of methylaminoethanol and adipic acid. To this was added 108 grams of the CLC composition. The mixture was stirred using a Silverson mixer at 5000 rpm. It was then passed through a microfluidizer at 3000 psi. Finally, the resulting dispersion was passed through a 23 μm filter. The droplet size distribution in the dispersion was measured using a Coulter Counter. It was found that the mean size was 9.7 microns with a coefficient of variation (cv) of 0.14.

The above dispersion was mixed with an aqueous solution of fish skin gelatin from Norland Products Inc. having a weight-average molecular weight of 83,800 and a polydispersity of 3.4, an aqueous solution of polyvinylalcohol (PVA)(type GL-05 from Nippon Gohsei Limited), a solution of Aerosol OT in water and a solution of bis(vinylsulfonyl) methane in water to give a coating composition containing 15% w/w CLC material, 4.5% fish skin gelatin, 0.5% PVA, 0.07% Aerosol OT coating aid and 0.1% bis(vinylsulfonyl) methane crosslinker. The composition was spread over a plastic support with a thin layer of indium tin oxide (ITO) at 37.67 cm^3/m^2 to give a dry uniform coverage of about 5400 mg/m^2 of CLC material. The PVA prevented agglomeration of the liquid crystal domains during self-assembly and helped minimize defects in the coating. The plastic support (Dupont ST504) with a sputter coated ITO conductive layer (300 ohm/sq resistivity) was obtained from Bekaert. The thickness of the ITO layer is approximately 240 Angstroms. During the operation, the plastic support was placed over a coating block that was maintained at room temperature (23° C.) and the coating composition was also delivered or applied at the same temperature. The resulting coating was then dried under ambient conditions (23° C.). The fish gelatin does not chill set at room temperature and, thus, had not chill set at the onset of drying.

A sample of the dried coating was positioned facing a helium-neon laser (Spectra Physics model 155A). A screen was placed behind the sample. The distance from the source of laser light to the sample was 20.6 cm and the distance from the sample to the screen was 10.5 cm. As shown in FIG. 1, the invention coating showed diffraction rings on the screen caused by Fraunhofer diffraction of light indicating an ordered close-packed monolayer of CLC droplets in the coating.

Method 2 (Control)

A dispersion of the CLC composition with CWR at 540 nm was prepared as follows. To 172.1 grams of distilled water was added 2.6 grams of Ludox™ colloidal silica suspension and 5.3 grams of a 10% w/w aqueous solution of a copolymer of methylaminoethanol and adipic acid. To this was added 77.2 grams of the CLC composition. The mixture was stirred using a Silverson mixer at 5000 rpm. It was then passed through a microfluidizer at 3000 psi. Finally, the resulting dispersion was passed through a 23 μm filter. The droplet size distribution in the dispersion was measured using a Coulter Counter. It was found that the mean size was 9.4 microns with a coefficient of variation (cv) of 0.14.

The above dispersion was mixed with an aqueous solution of conventional Type IV cattle gelatin having a weight-average molecular weight of 229,000 and a polydispersity of 5.4, a solution of Alkanol XC in water and a solution bis(vinylsulfonyl)methane in water to give a coating composition containing 8% w/w CLC material, 5% gelatin, 1% Alkanol XC coating aid and 0.05% bis(vinylsulfonyl)methane crosslinker. The composition was then spread over a plastic support with a thin layer of indium tin oxide (ITO) to give a uniform coverage of about 5400 mg/m^2. The plastic support (Dupont ST504) with a sputter coated ITO conductive layer (300 ohm/sq resistivity) was obtained from Bekaert. The thickness of the ITO layer is approximately 240 Angstroms. During the operation, the coating block was maintained at a temperature close to room temperature (23° C.) and the coating composition was delivered or applied at a temperature of 45° C. The resulting coating was then dried under ambient conditions (23° C.). It should be noted that conventional gelatin will chill set at this temperature prior to the onset of drying since the sol-gel transition temperature of conventional gelatin is above room temperature.

A sample of this coating was inspected using the same laser light source under the same conditions as before. As shown in FIG. **2**, in this case the diffraction pattern is distinctly different, indicative of a very disordered or random coating of the CLC droplets.

EXAMPLE 2

This example illustrates the improved electro-optical properties of a device fabricated according to the invention compared to a control device.

Method I (Invention)

A dispersion of CLC material was prepared in a manner similar to Method I of Example 1.

The dispersion was mixed with an aqueous solution of Type IV cattle gelatin having a weight-average molecular weight of 117,000 and a polydispersity of 3.7, an aqueous solution of polyvinylalcohol (PVA)(type GL-05 from Nippon Gohsei Limited), a solution of Aerosol OT in water and a solution bis(vinylsulfonyl)methane in water to give a coating composition containing 15% w/w CLC material, 4.5% gelatin, 0.5% PVA, 0.07% Aerosol OT and 0.1% bis(vinylsulfonyl)methane. The composition was spread over a plastic support with a thin layer of indium tin oxide (ITO) to give a uniform coverage of about 5400 mg/m^2 of CLC material. The coated layer was referred to as layer 1. During the operation, the plastic support was placed over a coating block that was maintained at a temperature of 45° C. and the coating composition was also delivered or applied at the same temperature.

The resulting coating was then dried at 45° C. The coating was kept aside for 48 hours to allow the crosslinking of gelatin to go to completion. Analysis of a portion of the coating by laser light as in Example 1 showed rings due to Fraunhofer diffraction of light. Analysis of a second portion of the coating by x-ray diffraction showed a complete absence of triple helix structure in gelatin. In other words, the gelatin molecules in layer 1 were in a random coil configuration. The coating was then placed on a coating block that was maintained at 23° C. A 4% w/w solution of Type IV cattle gelatin was then coated over layer 1 at a uniform wet coverage of about 28 cm^3/m^2. This second layer was referred to as layer 2. The coating was then dried at room temperature (23° C.).

Analysis of a portion of the coating by x-ray diffraction now showed a peak at low angle associated with the triple

helix structure of gelatin indicating that at least some of the gelatin molecules in layer 2 were in the triple helix configuration. Analysis by laser light showed that the close-packed structure had been preserved even after the second layer had been applied. A carbon-based conductive ink (Electrodag 423SS from Acheson Corporation) was then screen printed on top of layer 2 to complete the construction of the display device.

The electro-optic response of the device is shown in FIG. **3**. The horizontal axis is the amplitude of the addressing voltage pulse and the vertical axis is the reflectance of the CLC material measured at 0 volts about 2 seconds after application of the addressing pulse. The reflectance was measured using an X-rite 938 spectrodensitometer. The addressing pulse was a square wave with frequency of 250 Hz and duration of 100 milliseconds. The open circles represent the response when the material was initially in the planar texture and the filled circles represent the response when the material was initially in the focal conic state. A voltage pulse higher than 70 volts (V4) switched the display into the reflecting state and a voltage pulse between 44 and 54 volts (V2 and V3 respectively) switched the display into the weakly scattering or dark state. Voltages less than V1 (8 volts) did not influence the state of the display. In this case the quantity Vqm, defined as 2V1/(V4−V3), was equal to 1. For a multi-row and column matrix display using conventional drive it is important that Vqm is greater than or equal to 1 to ensure maximum contrast without cross-talk.

Method 2 (Control)

A dispersion of CLC material and coating composition were prepared in a manner similar to Method 2 of Example 1. The composition was coated as described under Method 2 of Example 1. A carbon-based conductive ink (Electrodag 423SS from Acheson Corporation) was then screen printed on top of the coating to create the display device. The electro-optic response of the device is shown in FIG. **4**. In this case, a voltage pulse higher than 130 volts (V4) switched the display into the reflecting (bright) state and a voltage pulse between 44 and 64 volts (V2 and V3 espectively) switched the display into the weakly scattering or dark state. The contrast ratio defined as the reflectance of the bright state divided by that of the dark state was 15.8. Voltages less than 14 volts (V1) did not influence the state of the display. Based on these parameters Vqm was only 0.42.

It is clear that the voltage needed to switch the display into the reflecting state was significantly greater than that of the invention device. Furthermore, the contrast of a multiplexed display based on this method may be greatly inferior compared to the method of the invention because of the relatively low value of Vqm.

EXAMPLE 3

Invention

A dispersion of CLC material and coating composition were prepared as described under Method 1 of Example 1. The composition was spread over a plastic support (Dupont ST504) with a thin layer of ITO (approximately 240 Angstroms in thickness and 300 ohm/sq resistivity) at 37.7 cm^3/m^2 to give a uniform dry coverage of about 5400 mg/m^2 for the CLC material. During the operation, the plastic support was placed over a coating block that was maintained at 45 C and the coating composition was delivered at 23 C.

within the meaning of 35 U.S.C. § 285, and ITRI is entitled to recover its reasonable and necessary attorneys' fees, costs, and expenses.

XIII. INFRINGEMENT OF U.S. PATENT NO. 7,339,716

105. On March 4, 2008, the USPTO issued U.S. Patent No. 7,339,716, entitled "Transflective Electrophoretic Display Device" (hereinafter "the '716 patent"). A true and correct copy of the '716 patent is attached hereto as Exhibit K.

106. ITRI is the owner of all right, title, and interest in and to the '716 patent by assignment, with full right to bring suit to enforce the patent, including the right to recover for past infringement damages and the right to recover future royalties, damages, and income.

107. The '716 patent is valid and enforceable.

108. All requirements under 35 U.S.C. § 287 have been satisfied with respect to the '716 patent.

109. Samsung has been and is infringing the '716 patent by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '716 patent, including but not limited to Samsung products bearing flat panel displays such as the Samsung Alias 2.

110. Samsung has been and is continuing to induce infringement of the '716 patent under 35 U.S.C. § 271(b) and contributes to the infringement of the '716 patent under 35 U.S.C. § 271(c), in conjunction with such acts of making, using, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '716 patent. The infringing instrumentalities have no substantial non-infringing uses.

The resulting coating of the imaging layer was dried at 45 C. All of these temperatures were above the sol-gel transition temperature of the binder.

The coating of the imaging layer was kept aside for 48 h to allow the cross-linking of gelatin to go to completion. The coating was then placed on a coating block that was maintained at 30 C. A composition containing 4% Type IV cattle gelatin, 1.4% carbon black and 0.1% Aerosol OT in distilled water was then spread over it using a coating knife with 0.008 cm gap to constitute the protective overcoat. The coating was dried at 30 C. For this top layer or protective overcoat, the temperature of the coating block and the drying temperature were both below the sol-gel transition temperature of the binder. A silver-based conducting ink was then screen printed over the dried protective layer to complete construction of the display device. The electro-optic response of this device is shown in FIG. 5. A voltage pulse higher than 72 volts (V4) switched the display into the reflecting state and a voltage pulse between 32 and 44 volts (V2 and V3 respectively) switched the display into the weakly scattering or dark state. The contrast ratio was 33.1.

It is clear that the voltages needed to switch the display into the bright state and the dark state were considerably lower than those for the control.

Furthermore, the contrast ratio was significantly higher indicating a much improved display at low voltage.

EXAMPLE 4

Invention

This example illustrates the uniformity of thickness of the imaging layer using the method of the invention. It is preferred that the RMS surface roughness is less than 1.5 microns, it is more preferred that the RMS surface roughness is less than 1.0 microns and it is most preferred that the RMS surface roughness is less than 0.5 microns. (reasons for the uniformity of thickness are in the prior art section).

A dispersion of CLC material and coating composition were prepared as described under Method 1 of Example 1. The composition was spread over a plastic support (Dupont ST504) with a thin layer of ITO (approximately 240 Angstroms in thickness and 300 ohm/sq resistivity) at 37.7 cm^3/m^2 to give a uniform dry coverage of about 5400 mg/m^2 for the CLC material. During the operation, the plastic support was placed over a coating block that was maintained at 45 C and the coating composition was delivered at 23 C. The resulting coating of the imaging layer was dried at 45 C. All of these temperatures were above the sol-gel transition temperature of the binder.

The coating of the imaging layer was kept aside for 48 hours to allow the crosslinking of gelatin to go to completion. The surface roughness profile was then obtained using a Zeiss LSM 510 laser scanning microscope from Carl Zeiss Microimaging Inc., One Zeiss Drive, Thornwood N.Y. 10594. FIG. 9 shows a micrograph of the coating of the imaging layer along with the surface roughness profile. The roughness profile shows the variation in thickness as a function of distance along a line drawn across the surface of the coating. From such a profile it is possible to calculate the root mean square (RMS) surface roughness (see for example Wyko NT8000 Set Up and Operation Guide June 2003 version 3.01 Veeco Industries Inc. 2650 East Elvira Road, Tuscon Ariz. 85706). For this coating the RMS surface roughness was about 0.4 microns.

The coating was then immersed in acetone to remove the liquid crystal material. After removal of the liquid crystal

material, the coating was once again examined using the laser confocal microscope. The corresponding micrograph is shown in FIG. 10. The coating now shows well-defined cavities in areas that were originally occupied by droplets of the liquid crystal. Note that the crosslinked binder resisted dissolution. In other words, cross-linking the binder allowed the close-packed structure to be fixed or locked into place. The attached profile shows that the imaging layer had a uniform thickness of about 5 microns.

EXAMPLE 5

Control

This example illustrates the effect of using a polymer latex as the binder material in the imaging layer instead of gelatin.

A CLC composition with CWR at 450 nm was prepared by adding the appropriate amount of a high twist chiral dopant to the nematic host mixture BL087 obtained from Merck, Darmstadt, Germany.

A dispersion of the CLC composition with CWR at 450 nm was prepared as follows. To 166 grams of distilled water was added 2.6 grams of Ludox™ colloidal silica suspension and 5.1 grams of a 10% w/w aqueous solution of a copolymer of methylaminoethanol and adipic acid. To this was added 74.6 grams of the CLC composition. The mixture was stirred using a Silverson mixer at 5000 rpm. It was then passed through a microfluidizer at 3000 psi. Finally, the resulting dispersion was passed through a 23 μm filter. The droplet size distribution in the dispersion was measured using a Coulter Counter. It was found that the mean size was 9.4 microns with a coefficient of variation (cv) of 0.14.

The above dispersion was mixed with an aqueous suspension of polyurethane polymer latex NeoRez R-967 from NeoResins, Wilmington Mass., USA and a solution of coating aid Olin 10 G in water to give a coating composition containing 15% w/w CLC material, 5.0% polymer latex and 0.1% Olin 10 G. The composition was spread over a plastic support with a thin layer of indium tin oxide (ITO) using a coating knife with 0.008 cm gap. The plastic support (Dupont ST504) with a sputter coated ITO conductive layer (300 ohm/sq resistivity) was obtained from Bekaert. The thickness of the ITO layer is approximately 240 Angstroms. During the operation, the plastic support was placed over a coating block that was maintained at room temperature (23° C.) and the coating composition was also delivered or applied at the same temperature. The resulting coating was then dried under ambient conditions (23° C.). The coating was then placed on a coating block that was maintained at 23 C. A composition containing 4% Type IV cattle gelatin and 0.1% Aerosol OT in distilled water was then spread over it using a coating knife with 0.008 cm gap to constitute the protective overcoat. The coating was dried at 23 C. For this top layer or protective overcoat, the temperature of the coating block and the drying temperature were both below the sol-gel transition temperature of the binder. A carbon-based conductive ink (Electrodag 423SS from Acheson Corporation) was then screen printed over the protective overcoat to complete the construction of the display device.

The electro-optic response of the device is shown in FIG. 11. The horizontal axis is the amplitude of the addressing voltage pulse and the vertical axis is the reflectance of the CLC material measured at 0 volts about 2 seconds after application of the addressing pulse. The reflectance was measured using an X-rite 938 spectrodensitometer. The addressing pulse was a square wave with frequency of 250 Hz and duration of 100 milliseconds. The open circles

represent the response when the material was initially in the planar texture and the filled circles represent the response when the material was initially in the focal conic state. A voltage pulse higher than 138 volts (V4) switched the display into the reflecting state and a voltage pulse between 64 and 86 volts (V2 and V3 respectively) switched the display into the weakly scattering or dark state. Voltages less than V1 (12 volts) did not influence the state of the display. In this case the quantity Vqm, defined as 2V1/(V4−V3), was equal to 0.46. Once again it is clear that the voltage needed to switch the display into the reflecting state was significantly greater than that of the invention device. Furthermore, the contrast of a multiplexed display based on this method may be greatly inferior compared to the method of the invention because of the relatively low value of Vqm.

EXAMPLE 6

Those skilled in the art will appreciate that the phase-separated polymer domains are established or the monomer is polymerized after the emulsion domains have been formed around the liquid crystal, polymer mixture. In order to obtain at the black-white appearance of the display cell, the intrinsic pitch P_o of the cholesteric material is adjusted so that nP_o is around 600 nm (from orange color to red color), where n is the average refractive index of material. nP_o determines the limit of the long wavelength side of the reflection spectrum.

A few percent polymer network is dispersed in the liquid crystal material. The polymer concentration is chosen to be about 3%. The polymer concentration should be high enough to cause the helical axes of the planar liquid crystal domains to distribute in a cone of angle around 40°, but be low enough not to cause too much scattering when the liquid crystal is in the weakly scattering focal conic texture. When the domains are in the planar texture, the material has a white appearance, while when the domains are in the focal conic texture, the material has a black appearance or whatever the color of the absorption layer is.

When a predetermined voltage value is applied to the cell and then removed to place the liquid crystal material in the reflecting planar texture, the helical axes of the cholesteric liquid crystal in the polymer domains are oriented along various directions around the normal of the cell. Under room light conditions, where light is incident on the cell from all directions, the light reflected from different domains has different colors because the incident angles in different domains are different. As such, the light observed by a human eye is an average of the reflection bands centered at different wavelengths, and has a white appearance. Therefore, when a voltage is supplied to the cell to drive the liquid crystal material into the focal conic texture and then removed, the orientation of the helical axes in the domains are essentially parallel to the cell surface. As such, the incident light is either diffracted or scattered in the forward direction and absorbed by an absorption layer at the bottom of the display. Since the absorption layer has a black color, the polymer domains associated with the focal conic texture appear black.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

The invention claimed is:

1. A high contrast reflective display comprising at least one substrate, at least one electrically conductive layer and at least one electronically modulated imaging layer, wherein said electronically modulated imaging layer comprises a close-packed, ordered monolayer of domains of electrically modulated material in a fixed polymer matrix.

2. The high contrast reflective display of claim 1 wherein said substrate is flexible.

3. The high contrast reflective display of claim 1 wherein said substrate is transparent.

4. The high contrast reflective display of claim 3 further comprising a second substrate.

5. The high contrast reflective display of claim 1 wherein said electrically conductive layer a surface conductivity of less than 10^4 ohms/sq.

6. The high contrast reflective display of claim 1 wherein said electrically conductive conductive layer comprises ITO.

7. The display of claim 1 wherein said electrically conductive layer comprises polythiophene.

8. The high contrast reflective display of claim 1 further comprising at least a second electrically conductive layer, wherein said at least one close-packed, ordered monolayer of electrically modulated material in a crosslinked polymer matrix is between said at least one electrically conductive layer and said second conductive layer.

9. The high contrast reflective display of claim 1 wherein at least one electrically conductive layer is patterned.

10. The high contrast reflective display of claim 1 further comprising a means for applying electrical field across said at least one close-packed, ordered monolayer of electrically modulated material in a fixed polymer matrix.

11. The high contrast reflective display of claim 1 wherein said electrically modulating material is a liquid crystalline material.

12. The high contrast reflective display of claim 1 wherein said electrically modulated material comprises a bistable liquid crystalline material.

13. The high contrast reflective display of claim 12 wherein said bistable liquid crystalline material comprises a chiral nematic liquid crystal layer.

14. The high contrast reflective display of claim 1 wherein said at least one close-packed, ordered monolayer of electrically modulated material is a hexagonally closest packed monolayer of light modulating material.

15. The high contrast reflective display of claim 1 wherein said at least one close-packed, ordered monolayer of electrically modulated material has a repeat pattern or periodicity with a repeat distance of the order of the wavelength of visible light.

16. The high contrast reflective display of claim 1 wherein said fixed polymer matrix is a crosslinked polymer matrix.

17. The high contrast reflective display of claim 1 wherein said fixed polymer matrix is not rigid prior to drying.

18. The high contrast reflective display of claim 1 wherein said fixed polymer matrix is in a random configuration if the coating is dried at a temperature that is above the sol-gel transition temperature.

19. The high contrast reflective display of claim 1 wherein said fixed polymer matrix prior to crosslinking has a sol-gel transition temperature or thermal gelation temperature or chill set temperature below 23° C.

20. The high contrast reflective display of claim 1 wherein said fixed polymer matrix prior to crosslinking has a sol-gel transition temperature or thermal gelation temperature or chill set temperature below 10° C.

21. The high contrast reflective display of claim 1 wherein said electrically modulated material to said fixed polymer matrix ratio is from 6:1 to 0.5:1.

22. The high contrast reflective display of claim 1 wherein said electrically modulated material to said fixed polymer matrix ratio is 3:1.

23. The high contrast reflective display of claim 1 wherein said fixed polymer matrix comprises gelatin.

24. The high contrast reflective display of claim 23 wherein said gelatin is in a random coil configuration if the coating is dried at a temperature that is above the sol-gel transition temperature of gelatin.

25. The high contrast reflective display of claim 23 wherein said gelatin is fish gelatin.

26. The high contrast reflective display of claim 25 wherein said fish gelatin is deep water fish gelatin.

27. The high contrast reflective display of claim 23 wherein said gelatin has lower imino acid content than bovine gelatin.

28. The high contrast reflective display of claim 1 wherein said fixed polymer matrix further comprises a hardening agent.

29. The high contrast reflective display of claim 1 further comprising a protective layer.

30. The high contrast reflective display of claim 29 wherein said protective layer comprises gelatin.

31. The high contrast reflective display of claim 30 wherein said gelatin contains molecules in a helix configuration.

32. The high contrast reflective display of claim 1 wherein said electrically modulated imaging layer further comprises polyvinylalcohol (PVA).

33. The high contrast reflective display of claim 1 wherein said at least one electronically modulated imaging layer has a RMS surface roughness of less than 1.5 microns.

34. The high contrast reflective display of claim 1 comprising a stack of at least two of said high contrast reflective displays, wherein a stack comprises at least one substrate, at least one electrically conductive layer and at least one close-packed, ordered monolayer of domains of electrically modulated material in a fixed polymer matrix.

35. A method of making a high contrast reflective display comprising:

providing a substrate;

applying a conductive layer;

applying at least one layer of domains of electrically modulated material in a polymer matrix;

drying the at least one applied layer of said domains of electrically modulated material in a polymer matrix at a temperature above the chill set temperature or sol-gel transition temperature of said polymer matrix to permit self-assembly of said domains of electrically modulated material into a close-packed monolayer of said domains of electrically modulated material; and

fixing said polymer matrix to preserve said close-packed monolayer of domains of electrically modulated material.

36. The method of claim 35 further comprising:

applying a second aqueous layer containing gelatin;

chill setting said second aqueous layer containing gelatin; and

drying said second aqueous layer.

37. The high contrast reflective display of claim 1 wherein said at least one electronically modulated imaging layer further comprises a chiral nematic liquid crystal light modulating material having positive dielectric anisotropy and a pitch length effective to reflect light of approximately 600 nm and a UV curable polymer, wherein said chiral nematic liquid crystal light modulating material and said UV curable polymer cooperate to form focal conic texture and twisted planar texture that are stable in the absence of a field, and wherein said twisted planar texture is light reflecting and appears substantially white.

38. The high contrast reflective display of claim 37 wherein said twisted planar texture appears substantially white and wherein said focal conic texture is weakly scattering and appears as the same color as the rearmost surface of the display.

39. The high contrast reflective display of claim 37 further comprising a color contrast layer, wherein said focal conic texture appears substantially the same color as said color contrast layer.

40. The high contrast reflective display of claim 39 wherein said color contrast layer is black.

41. The high contrast reflective display of claim 37 wherein said UV curable polymer is present in an amount of 3% based on the total weight of said UV curable and said chiral nematic liquid crystal light modulating material.

* * * * *

York, having its principal place of business at 105 Challenger Road, Ridgefield Park, New Jersey 07660.

3. Upon information and belief, Samsung Telecommunications America, L.L.C. is, and at all relevant times mentioned herein was, a limited liability company organized under the laws of Delaware, having a principal place of business at 1301 East Lookout Drive, Richardson, Texas 75082.

4. Upon information and belief, Samsung Electronics Co., Ltd. is, and at all relevant time mentioned herein was, a corporation organized under the laws of Korea, having its principal place of business at 1320-10, Seocho 2-dong, Seocho-gu, Seoul 137-857 Korea. Upon information and belief, Samsung Electronics Co., Ltd. is a nonresident of Arkansas that engages in business in this state, but does not maintain a regular place of business in this state or a designated agent for service of process in this state. Samsung Electronics Co., Ltd may be served with process in Korea pursuant to the Hague Convention on the Service Abroad of Judicial and Extrajudicial Documents. Samsung Electronics America, Inc., Samsung Telecommunications America, L.L.C., and Samsung Electronics Co., Ltd will be collectively referred to as "Samsung."

II. JURISDICTION AND VENUE

5. This is an action for patent infringement arising under the patent laws of the United States, Title 35, United States Code. The Court's jurisdiction is proper under the above statutes, including 35 U.S.C. § 271 et. seq., and 28 U.S.C. §§ 1331 and 1338(a).

6. This Court has personal jurisdiction over each Defendant. Each Defendant has conducted and does conduct business within the State of Arkansas. Each

111. As a direct and proximate result of Samsung's acts of patent infringement, ITRI has been and continues to be injured and has sustained and will continue to sustain substantial damages.

112. Unless Samsung is enjoined by this Court from continuing their infringement of the '716 patent, ITRI will suffer additional irreparable harm and impairment of the value of its patent rights.

113. ITRI has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and ITRI is entitled to recover its reasonable and necessary attorneys' fees, costs, and expenses.

XIV. INFRINGEMENT OF U.S. PATENT NO. 7,387,858

114. On June 17, 2008, the USPTO issued U.S. Patent No. 7,387,858, entitled "Reflective Display Based on Liquid Crystal Materials" (hereinafter "the '858 patent"). A true and correct copy of the '858 patent is attached hereto as Exhibit L.

115. ITRI is the owner of all right, title, and interest in and to the '858 patent by assignment, with full right to bring suit to enforce the patent, including the right to recover for past infringement damages and the right to recover future royalties, damages, and income.

116. The '858 patent is valid and enforceable.

117. All requirements under 35 U.S.C. § 287 have been satisfied with respect to the '858 patent.

118. Samsung has been and is infringing the '858 patent by making, using, selling, offering for sale, and/or importing in or into the United States, without authority,

products that fall within the scope of one or more claims of the '858 patent, including but not limited to Samsung products bearing flat panel displays such as the Samsung mobile telephone Alias 2.

119. Samsung has been and is continuing to induce infringement of the '858 patent under 35 U.S.C. § 271(b) and contributes to the infringement of the '858 patent under 35 U.S.C. § 271(c), in conjunction with such acts of making, using, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '858 patent. The infringing instrumentalities have no substantial non-infringing uses.

120. As a direct and proximate result of Samsung's acts of patent infringement, ITRI has been and continues to be injured and has sustained and will continue to sustain substantial damages.

121. Unless Samsung is enjoined by this Court from continuing their infringement of the '858 patent, ITRI will suffer additional irreparable harm and impairment of the value of its patent rights.

122. ITRI has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and ITRI is entitled to recover its reasonable and necessary attorneys' fees, costs, and expenses.

XV. PRAYER FOR RELIEF

ITRI prays for the following relief:

A. A judgment that each Defendant has infringed and continues to infringe each of the patents-in-suit as alleged herein, directly and/or indirectly by way of inducing or contributing to infringement of such patents;

B. A judgment for an accounting of all damages sustained by ITRI as a result of the acts of infringement by each Defendant;

C. A judgment and order requiring each Defendant to pay ITRI damages under 35 U.S.C. § 284, including treble damages for willful infringement as provided by 35 U.S.C. § 284, and supplemental damages for any continuing post-verdict infringement up until entry of the final judgment with an accounting as needed, and any royalties determined to be appropriate;

D. A judgment and order requiring each Defendant to pay ITRI pre-judgment and post-judgment interest on the damages awarded;

E. A judgment and order finding this to be an exceptional case and requiring each Defendant to pay the costs of this action (including all disbursements) and attorneys' fees as provided by 35 U.S.C. § 285;

F. A preliminary and thereafter a permanent injunction against each Defendant's direct infringement, active inducements of infringement, and/or contributory infringement of each of the patents-in-suit as alleged herein, as well as against each Defendant's agents, employees, representatives, successors, and assigns, and those acting in privity or in concert with them; and

G. Such other and further relief as the Court deems just and equitable.

XVI. JURY DEMAND

ITRI hereby demands that all issues be determined by jury.

Dated: November 5, 2009

Respectfully submitted,

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EXHIBIT A

US006074069A

United States Patent [19]

Chao-Ching et al.

[11] Patent Number: 6,074,069

[45] Date of Patent: Jun. 13, 2000

[54] **BACKLIGHT SOURCE DEVICE WITH CIRCULAR ARC DIFFUSION UNITS**

[75] Inventors: **Hsu Chao-Ching**, Tianan; **Tzeng Gwo-Juh**, Taichung, both of Taiwan

[73] Assignee: **Industrial Technology Research Institute**, Hsinchu, Taiwan

[21] Appl. No.: **09/233,457**

[22] Filed: **Jan. 20, 1999**

[30] **Foreign Application Priority Data**

Nov. 17, 1998 [TW] Taiwan 87218955

[51] **Int. Cl.**^{7} **G01D 11/28**
[52] **U.S. Cl.** **362/26**; 362/31
[58] **Field of Search** 362/31, 26

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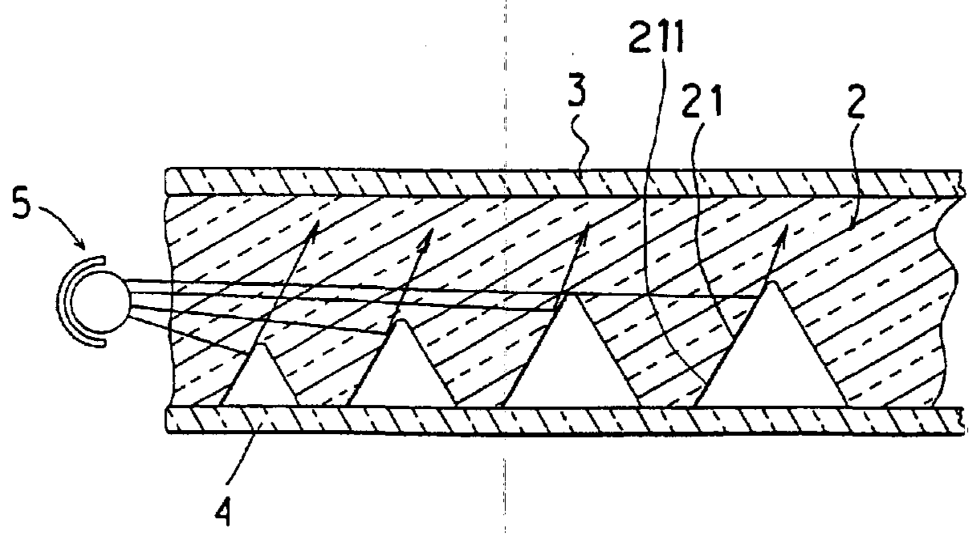
Primary Examiner—Laura K. Tso
Attorney, Agent, or Firm—Bacon & Thomas, Pllc

[57] **ABSTRACT**

A backlight source device with circular arc diffusion units includes a transparent guide plate with circular arc diffusion units on the front or rear surface of the plate. A diffusion piece above the guide plate, a reflecting piece below the guide plate, and a lateral light source. Therefore, the dark and light regions in the backlight source device may be removed so that the illumination of the backlight becomes stronger and more uniform.

13 Claims, 5 Drawing Sheets



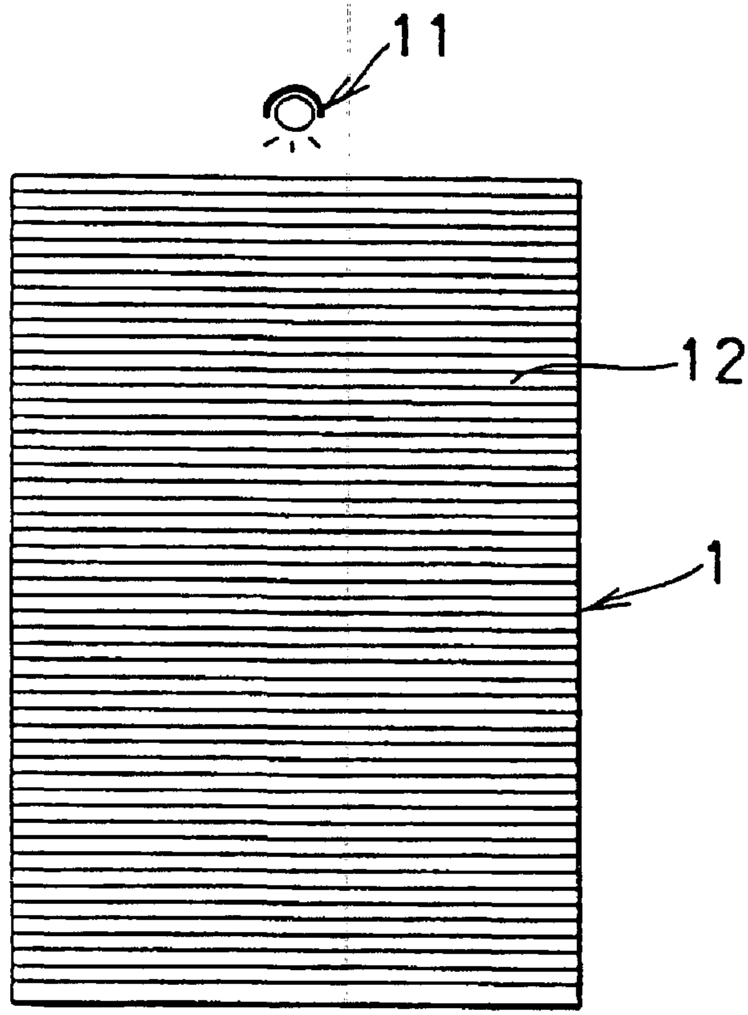


FIG. 1

PRIOR ART

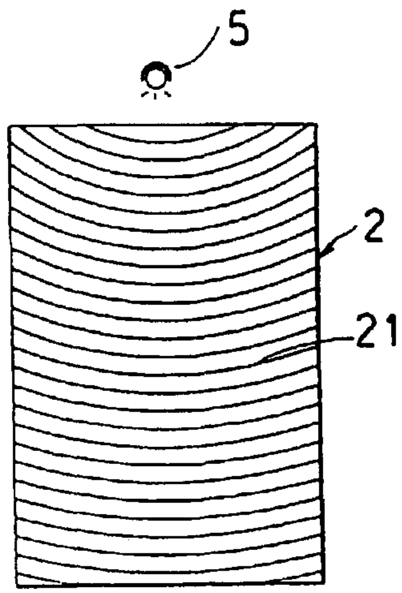


FIG. 2

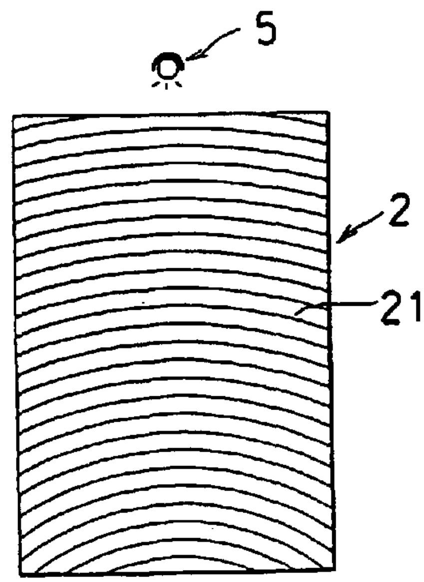


FIG. 3

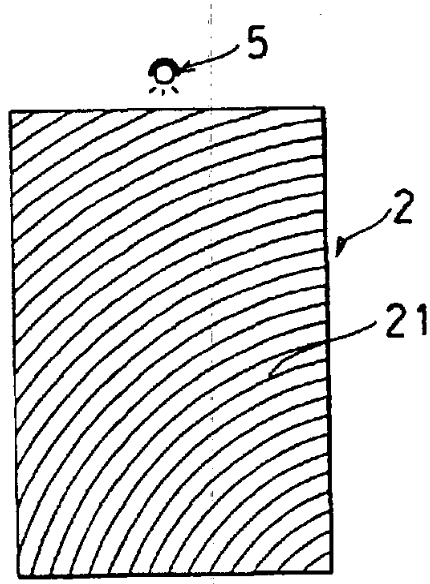


FIG. 4

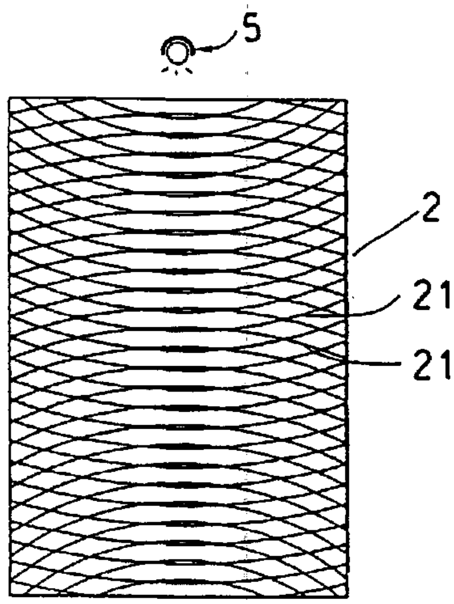


FIG. 5

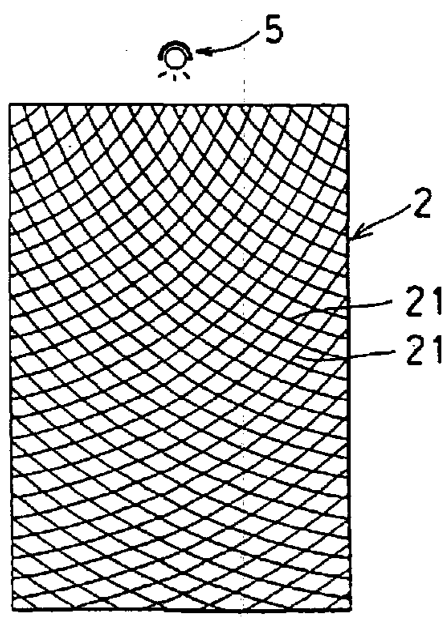


FIG. 6

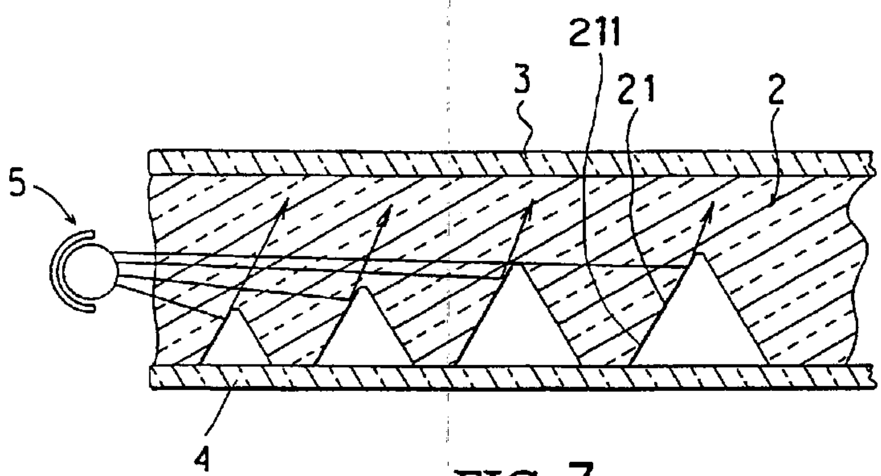


FIG. 7

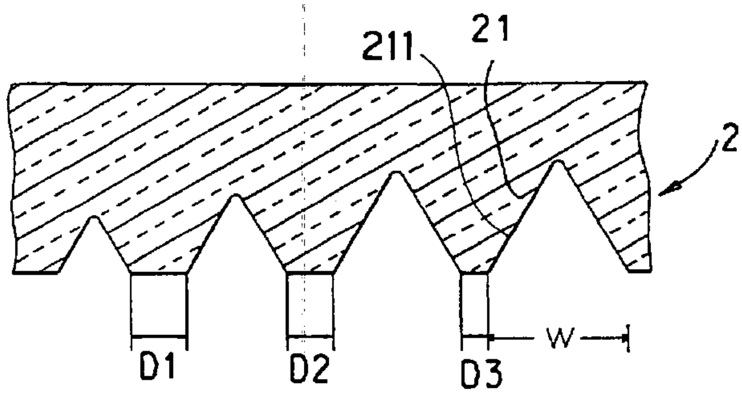


FIG. 8

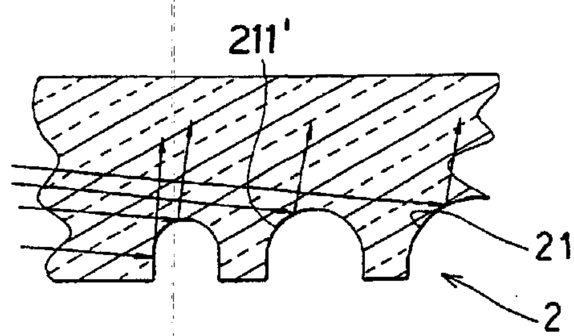


FIG. 9

Defendant, directly or through intermediaries (including distributors, retailers, and others), ships, distributes, offers for sale, and sells its products in the United States, the State of Arkansas, and the Western District of Arkansas. Each Defendant has purposefully and voluntarily placed one or more of its infringing products, as described below, into the stream of commerce with the expectation that they will be purchased by consumers in the Western District of Arkansas. These infringing products have been and continue to be purchased by consumers in the Western District of Arkansas. Each Defendant has committed the tort of patent infringement within the State of Arkansas and, more particularly, within the Western District of Arkansas.

7. Venue is proper in this Court under 28 U.S.C. §§ 1391(b), (c), and (d), as well as 28 U.S.C. § 1400(b), in that, on information and belief, each Defendant has committed acts within this judicial district giving rise to this action and does business in this district, including making sales and/or providing service and support for their respective customers in this district.

III. INFRINGEMENT OF U.S. PATENT NO. 6,074,069

8. On June 13, 2000, the United States Patent and Trademark Office ("USPTO") issued U.S. Patent No. 6,074,069, entitled "Backlight Source Device with Circular Arc Diffusion Units" (hereinafter "the '069 patent"). A true and correct copy of the '069 patent is attached hereto as Exhibit A.

9. ITRI is the owner of all right, title, and interest in and to the '069 patent by assignment, with full right to bring suit to enforce the patent, including the right to recover for past infringement damages and the right to recover future royalties, damages, and income.

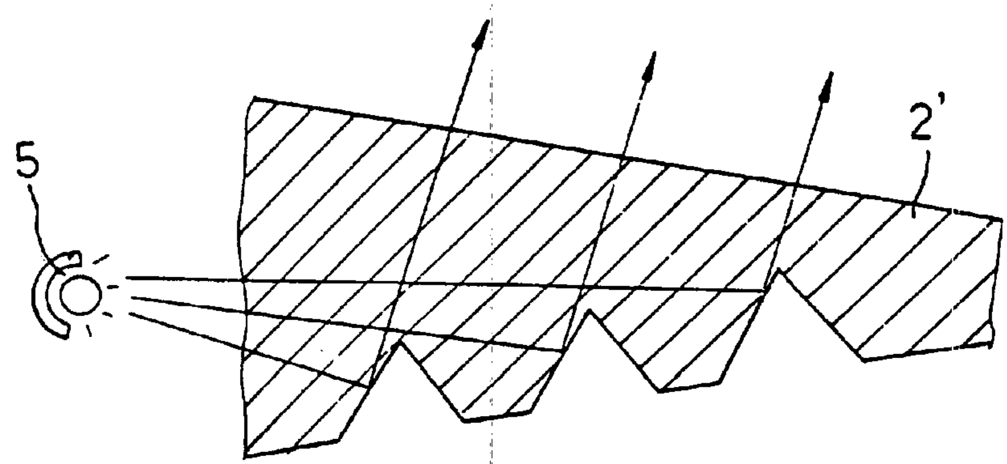


Fig. 10

BACKLIGHT SOURCE DEVICE WITH CIRCULAR ARC DIFFUSION UNITS

FIELD OF THE INVENTION

The present invention relates to a backlight source device, and especially to a backlight source device with circular arc diffusion units.

BACKGROUND OF THE INVENTION

The present invention is suitable for use in the fabrication of LCDs, backlight displays, backlight plate of slices, advertisement billboards and the other devices with a backlight source device.

With the improvement of technology, LCDs, backlight displays, backlight plate of slices, advertisement billboard and the other devices using a backlight source device must be used widely, and thus a backlight source device with improved uniform illumination is eagerly demanded.

A light guide plate **1** in the prior art is shown in FIG. **1**, which produces a printing pattern of a light guiding plate **1** of a lateral light source **11**. The pattern is formed by a plurality of trenches or convex strips, or matrix points, and other diffusion units, or a plurality of parallel trenches with equal spaces and depths for diffusing and reflecting light of a lateral light source.

The defects of the prior art backlight source device is that in printing, the useability of the light of the front face is relatively low. Since the angles of all the diffusion units can not be changed, the output direction of the diffusing light can not be controlled.

For example, for straight parallel trenches on the light guide plate of a backlight source device, a non-uniform light strip will be formed. The light reflected from the area near the middle of the radiating area of the lateral light source **11** is stronger than that farther from the middle, and trenches with equal space and depth can cause that the emitted light are to be distributed non-uniformly.

It is difficult to control the output angle of the output light from the light guide plate of a backlight source device, especially in the two sides of the diffusion unit **12**. In the place near the two sides of the diffusion units, the angle formed by the line between the lateral light source and the diffusion unit and the parallel lines of the diffusion units can not form a vertical projection so that the angle of light output can not be well controlled.

SUMMARY OF THE INVENTION

Accordingly, the object of the present invention is to provide a backlight source device having circular arc diffusion units so that the light reflected from a lateral light source becomes more uniform.

Another object of the present invention is to provide a backlight source device with circular arc diffusion units for preventing the formation of dark and light regions by the backlight source.

A further object of the present invention is to provide a backlight source device with circular arc diffusion units, in which a simplest design is used to control the light output angle of the backlight source device and the illumination thereof is improved greatly.

In order to attain the aforementioned objects, the backlight source device with circular arc diffusion units in the present invention includes a transparent guide plate with circular arc diffusion units on the front or rear surface thereof, each circular arc diffusion unit having a reflecting surface; a diffusion piece above the guide plate; a reflecting piece below the guide plate; and a lateral light source.

The circular arc diffusion units of the transparent guide plate are convex or concave diffusion units, and the thickness of the guide plate is decreased with the distance to the lateral light source for reducing the loss of light energy.

The circular arc diffusion units are distributed with unequal distances. The reflecting surfaces of the circular arc diffusion units have different heights which are increased with the distances to the lateral light source. The cross section of the circular arc diffusion units has a V or circular arc shape.

The projection area of the diffusion units on the guide plate may be increased with the distance to the lateral light source. The projection area of the diffusion units on the guide plate may be increased with the distance to the light lateral source, the width of the projection area is between 0.05 mm~1 mm.

The various objects and advantages of the present invention will be more readily understood from the following detailed description when read in conjunction with the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an elevation view of a prior art backlight source device.

FIGS. **2~6** are the elevation views for different embodiments of the backlight source device of circular arc diffusion units in the present invention.

FIGS. **7~10** are the lateral cross sectional and schematic views for different embodiments of the backlight source device of circular arc diffusion units in the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference now to FIGS. **2~9**, the backlight source device of the present invention mainly comprises a transparent light guide plate **2** made of plastic (Acryl, polycarbonate) or glass or from other transparent materials; a diffusion piece **3** above the light guide plate **2**, wherein a prism can be added above the light guide plate or the diffusion piece; a reflecting piece **4** below the light guide plate **2**; and a lateral light source **5** which is preferably a linear light source.

In the present invention, at the front or rear surface of the transparent light guide plate **2**, at least one surface has a plurality of circular arc convex diffusion units **21** (referring to FIGS. **7** or **8**) or concave diffusion units (referring to FIG. **9**). The cross section of each diffusion unit **21** may have a V shape (as shown in FIGS. **7** or **8**) or circular arc (as shown in FIG. **9**) or other proper shape, such as hyperbolic or elliptic shapes. The reflecting surfaces **211**,**211'** of the circular arc diffusion units may be smooth or coarse. If the surface is a mirror surface, then the diffusion effect will be reduced.

Further, in the present invention, the aforementioned plurality of diffusion units are distributed with unequal distances (referring to FIG. **8**, where D1>D2>D3). Preferably, in the present invention, the heights of the diffusion units **21** are increased to the distance with the lateral light source (as shown in FIGS. **7~9**).

The circular arc shape of the diffusion units **21** may assume an inverse direction (as shown in FIG. **3**), as compared to the opposite direction shown in FIG. **2**; or

distributed along a diagonal line (as shown in FIG. 4), and may be interlaced by two alternating diffusion units (as shown in FIGS. 5 and 6). Other distributions for arranging the circular arc diffusion units 21 are also included within the spirit of the present invention.

The diffusion units 21 of the transparent guide plate 2 of the present invention can be formed by cutting, discharging, etching, laser and other methods. The guide plate 2 can be made by injection, thermal pressing, extrusion molding, or other method.

The projection area of the diffusion units 21 on the guide plate 2 may be increased with the distance to the lateral light source, a preferred width W is 0.05 mm~1 mm. The thickness of the guide plate 2' can be decreased with the distance to the light source for reducing the loss of light energy, as shown in FIG. 10.

The Effect of the Present Invention

1. By the present invention, the reflecting light strength of the reflecting surface can be increased and the power loss is reduced, thus the average illumination of the backlight source device is increased.

2. In the present invention, the central line of the diffusion units are close to the light source to conveniently control the light output angle and thus to increase the illumination.

3. The dark and light regions in the backlight source device can be removed by the present invention so that the illumination of the backlight becomes more uniform.

4. The present invention is fabricated easily and there are many ways which may be used for producing the present invention.

In summary, in the present invention, circular arc diffusion units 21 are distributed on the guide plate 2 for deleting the dark and light regions of the backlight source device so that the illumination of the backlight area becomes more uniform and the illumination also increases.

Although the present invention has been described with reference to the preferred embodiments, it will be understood that the invention is not limited to the details described thereof. Various substitutions and modifications have been suggested in the foregoing description, and others will occur to those of ordinary skill in the art. Therefore, all such substitutions and modifications are intended to be embraced within the scope of the invention as defined in the appended claims.

What is claimed is:

1. A backlight source device with circular arc diffusion units comprising:

a transparent guide plate with a plurality of circular arc diffusion units on the front or rear surface thereof, each circular arc diffusion unit having a reflecting surface;

a diffusion piece above said guide plate;

a reflecting piece below said guide plate; and

a lateral light source.

2. The backlight source device with circular arc diffusion units as claimed in claim 1, wherein the circular arc diffusion units of the transparent guide plate are convex diffusion units.

3. The backlight source device with circular arc diffusion units as claimed in claim 1, wherein said circular arc diffusion units of the transparent guide plate are concave diffusion units.

4. The backlight source device with circular arc diffusion units as claimed in claim 1, wherein said circular arc diffusion units are distributed with unequal spaces.

5. The backlight source device with circular arc diffusion units as claimed in claim 1, wherein said reflecting surfaces of said circular arc diffusion units have different heights which are increased with the distances to said lateral light source.

6. The backlight source device with circular arc diffusion units as claimed in claim 1, wherein at least two sets of said circular arc diffusion units are alternatively interlaced on said light guide plate.

7. The backlight source device with circular arc diffusion units as claim in claim 1, wherein the cross section of said circular arc diffusion units has a V shape.

8. The backlight source device with circular arc diffusion units as claimed in claim 1, wherein the cross section of said circular arc diffusion units has a circular arc shape.

9. The backlight source device with circular arc diffusion units as claimed in claim 1, wherein the projection area of said diffusion units on said guide plate is increased with the distance to said lateral light source.

10. The backlight source device with circular arc diffusion units as claimed in claim 1, wherein the projection area of said diffusion units on said guide plate is increased with the distance to said lateral light source, and the width of the projection area is between 0.05 mm~1 mm.

11. The backlight source device with circular arc diffusion units as claimed in claim 1, wherein the thickness of the guide plate is decreased with the distance to said lateral light source for reducing the loss of photo energy.

12. The backlight source device with circular arc diffusion units as claimed in claim 1, wherein said circular arcs of said diffusion units are distributed in an inverse direction around the same center.

13. The backlight source device with circular arc diffusion units as claimed in claim 1, wherein said circular arcs of said diffusion units are distributed along a diagonal line.

* * * * *

EXHIBIT B

US006164791A

United States Patent [19]

Gwo-Juh et al.

[11] **Patent Number: 6,164,791**

[45] **Date of Patent: Dec. 26, 2000**

[54] **BACKLIGHT SOURCE DEVICE**

[75] Inventors: **Tzeng Gwo-Juh**, Da Li; **Hsu Chao-Ching**, Tianan, both of Taiwan

[73] Assignee: **Industrial Technology Research Institute**, Hsinchu, Taiwan

[21] Appl. No.: **09/274,101**

[22] Filed: **Mar. 23, 1999**

[30] **Foreign Application Priority Data**

Jan. 7, 1999 [TW] Taiwan 88200164

[51] **Int. Cl.**[7] **F21V 7/04**

[52] **U.S. Cl.** **362/31**; 362/330; 362/355

[58] **Field of Search** 362/31, 26, 27, 362/327, 339, 317, 330, 326, 340, 355, 246

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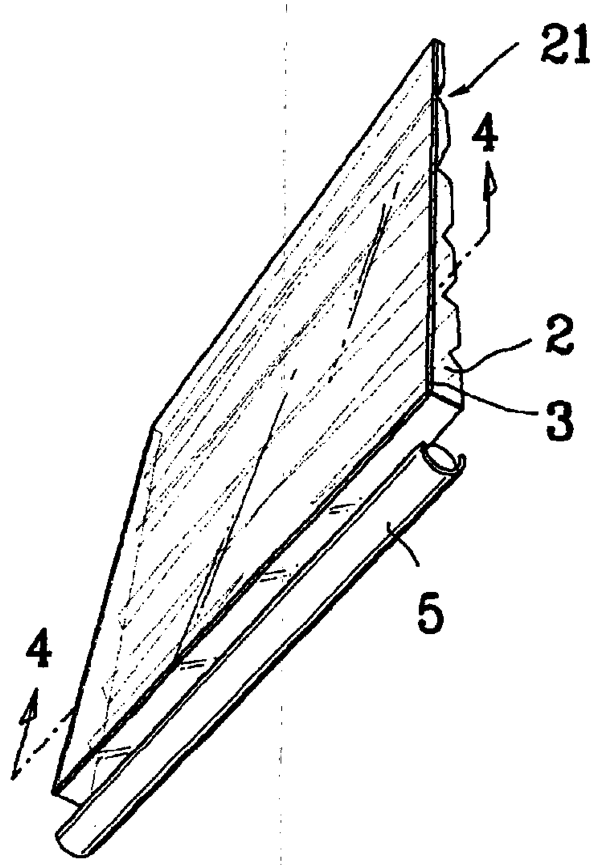
Primary Examiner—Sandra O'Shea
Assistant Examiner—Hargobind S. Sawhney
Attorney, Agent, or Firm—Bacon & Thomas, PLLC

[57] **ABSTRACT**

A backlight source device including a transparent light guiding plate, a diffusing piece on the transparent light guiding plate, a reflecting piece below the transparent light guiding plate and a lateral light source. Diffusing units are installed on either a front surface or a rear surface of the transparent light guiding plate. The diffusing units have respective light guiding surfaces with different areas which are extendedly and continuously arranged. The light reflected on the diffusing units by the lateral light source becomes substantially uniform such that light and dark regions of a backlight source device can be avoided. The light guiding surfaces of the backlight source device can be formed such that different illuminations of emitted light are easily formed and illuminated.

15 Claims, 4 Drawing Sheets



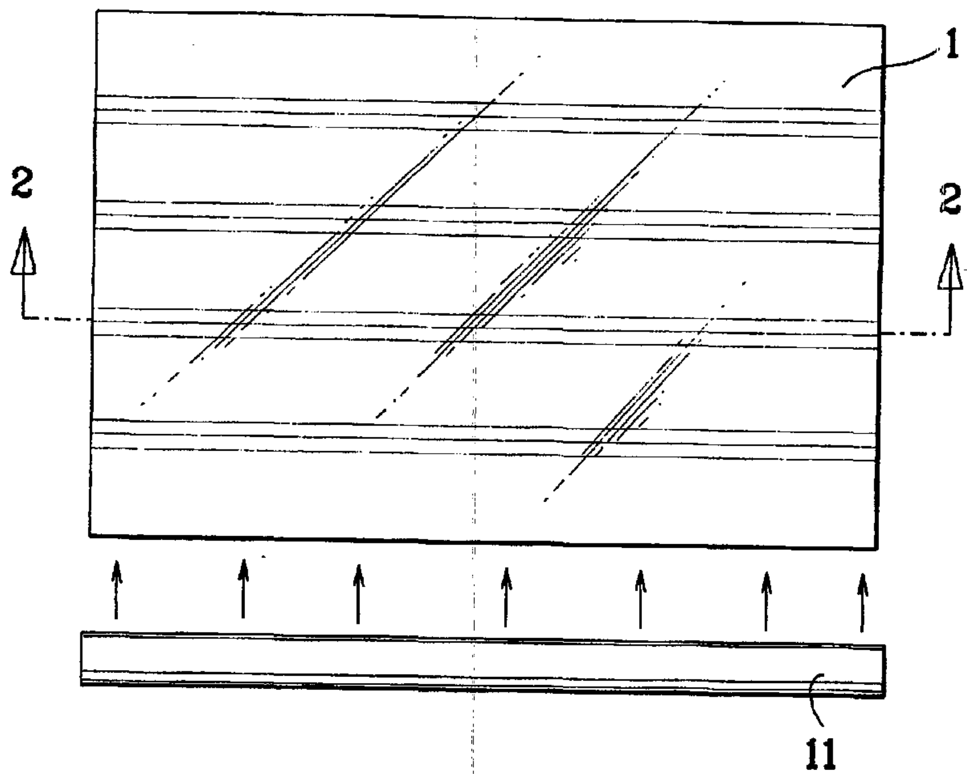


FIG.1

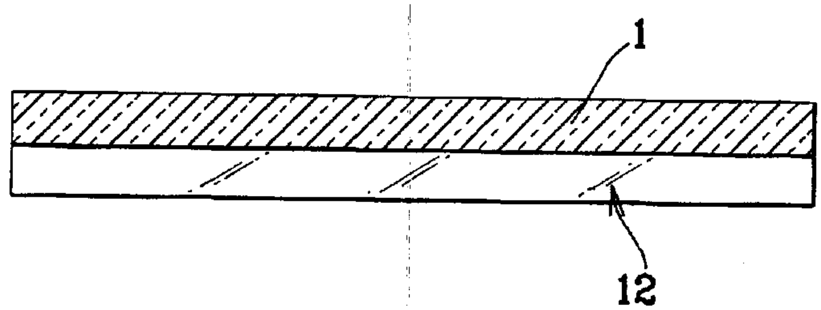


FIG.2

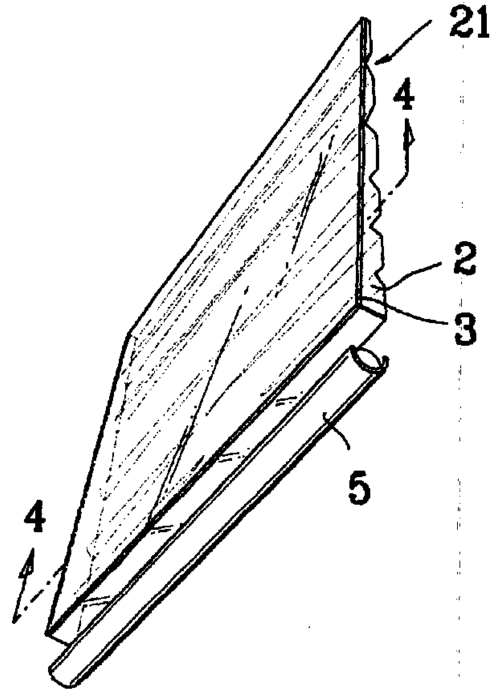


FIG.3

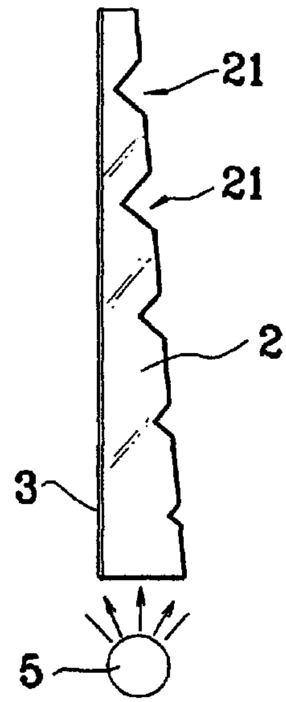


FIG.5

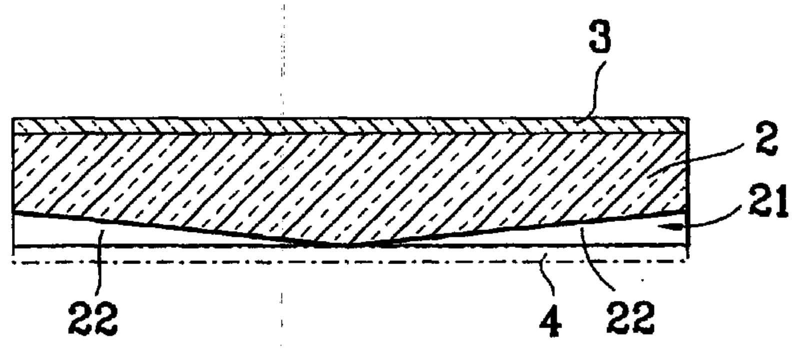


FIG.4

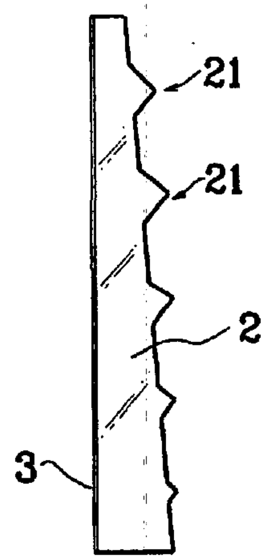


FIG.6

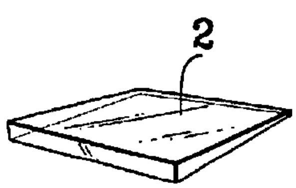


FIG.7

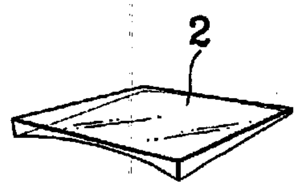


FIG.8

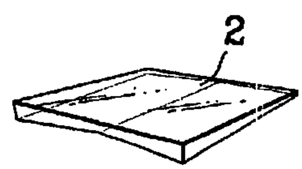


FIG.9

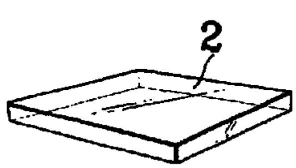


FIG.10

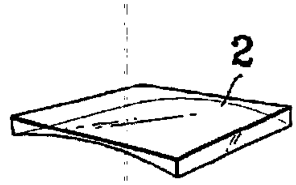


FIG.11

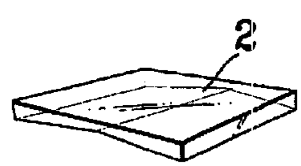


FIG.12

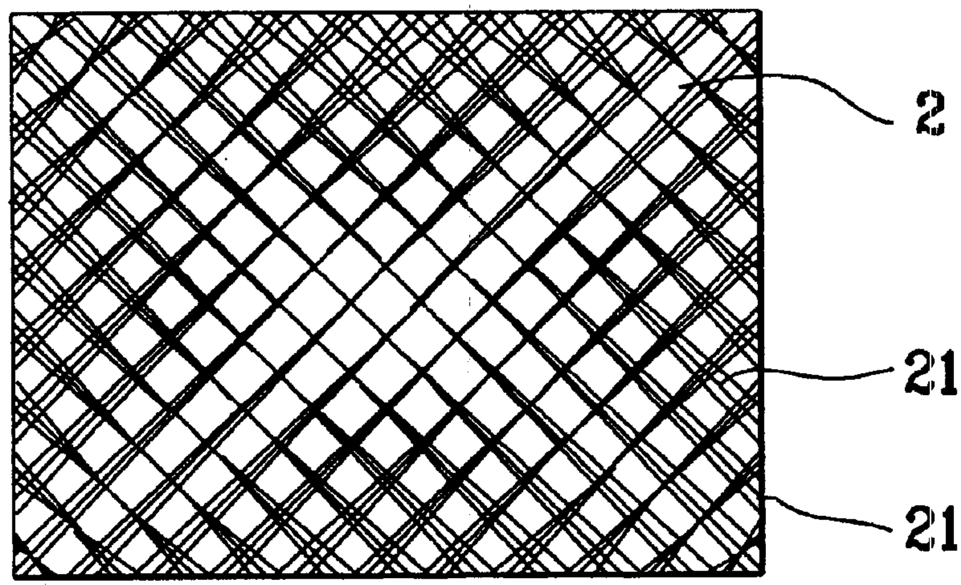


FIG.13

BACKLIGHT SOURCE DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a backlight source device suitable for a LCD, a display screen, a backlight plate, a broadcast plate, and other equipment having a backlight source device.

2. Description of the Prior Art

The light guiding plate **1** of a prior art backlight source device is disclosed in FIGS. **1** and **2**. The pattern for guiding lateral light source **11** is a plurality of trenches arranged in parallel formed by printing, or diffusing units formed by convex strips, or point matrix, or a plurality of trenches arranged in parallel with equal space and equal depth for diffusing and reflecting a lateral light source **11**. The areas of all parts of the light guiding surface **12** thereof are identical, and therefore, each part has identical illumination.

However, the light from the front surface of the light guiding plate **1** of the prior art backlight source device is not often used. Since the areas of all parts of the light guiding surface are identical, and therefore, each part has identical illumination. In general, the central portion of the lateral light source **11** has illumination stronger than that of the two sides thereof. Thus, the prior art light diffusng trenches with equal depths, height and arranged in parallel will induce a non-uniform light distribution of the prior art light guiding plate **1**. Namely, the portion near the central portion of the lateral light source **11** has stronger illumination, while the two sides of the lateral light source have weaker illumination. Thus, "light regions" and "dark regions" are formed. This is not an ideal circumstance.

SUMMARY OF THE INVENTION

Accordingly, the object of the present invention is to provide a backlight source device, by which the light reflected on the diffusing units by the lateral light source becomes more uniform.

Another object of the present invention is to provide a backlight source device, by which, the light regions and dark regions of a backlight source device are avoided.

A further object of the present invention is to provide a backlight source device, by which a plurality of light guiding surfaces of the backlight source device can be formed by a simple design. Thereby, different illuminations of emitted light are easily formed and the illumination thereof is improved greatly.

In order to achieve the aforementioned objects, a backlight source device of the present invention comprises a transparent light guiding plate; a diffusing piece on the transparent light guiding plate; a reflecting piece below the transparent light guiding plate; and a lateral light source. A plurality of diffusing units are installed on either front surface or rear surface of the transparent light guiding plate, the diffusing units have respective light guiding surfaces of different areas which are extendedly and continuously arranged.

In the present invention, the transparent light guiding plate can be formed by injecting, thermal pressing, extrusion, molding, etc. The diffusing units thereon can be formed by cutting, discharging, etching, laser cutting, etc. The diffusing unit has a convex shape or a concave shape. The lateral cross section of the diffusing unit has a V shape, a U shape, or other equivalent shape, and may be distributed with equal or unequal distance. The light guiding surfaces of

the diffusing units have an equal or unequal elevations. Preferably, the elevations of different light guiding surfaces are incremented with the distance increase to the lateral light source. The projecting area of the diffusing unit on the transparent light guiding plate is incremented as the distance from the lateral light source is increased. The thickness of the transparent light guiding plate may be identical or increased inversely proportional to the distance to the lateral light source for reducing the light energy loss or the weight and volume. The thickness of both sides of the transparent light guiding plate may be identical or increased with the distance to the middle thereof. As a consequence, when the transparent light guiding plate are finished in a specific depth, different projecting areas of the light guiding surfaces are extendedly arranged.

The light guiding surface is in parallel to said lateral light source or has an angle with the lateral light source. Even two sets of diffusing units are alternatively arranged with different angles and crossed over with each other to form a more uniform backlight effect. The areas of the light guiding surfaces increase with the distances to the middle of the light guiding plate. Thus, different areas of the light guiding surfaces are extendedly formed. The lateral light source may be a linear light source or a plurality of light sources arranged in one row.

The present invention will be better understood and its numerous objects and advantages will become apparent to those skilled in the art by referencing to the following drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an upper view of a prior art backlight source device.

FIG. **2** is a cross sectional view along the line **2—2** of FIG. **1**.

FIG. **3** is a perspective view of the embodiment of backlight source device according to the present invention.

FIG. **4** is a cross sectional view along the line **4—4** of FIG. **3**.

FIGS. **5** and **6** are two lateral schematic views showing two different embodiments of the backlight source devices of the present invention.

FIGS. **7–12** are perspective views of several different embodiments of the backlight source devices according to the present invention.

FIG. **13** is an upper view of another embodiment of the backlight source device according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Some embodiments of the present invention are described in the following so that the present invention may be further understood.

With reference to FIGS. **3–6**, the backlight source device of the present invention primarily comprises a transparent light guiding plate **2**, a diffusing piece **3**, a reflecting piece **4** (as the dashed line shown in FIG. **4**) and a lateral light source **5**. A plurality of diffusing units **21** are installed on the rear surface of the transparent light guiding plate **2** (shown in FIGS. **3**, **5** and **6**). The diffusing units **21** are spaced with an equal distance and have respective light guiding surfaces **22** of different areas (the detail is shown in FIG. **4**). The diffusing piece **3** and the reflecting piece **4** are installed above and below the transparent light guiding plate **2** and the lateral light source is a linear light source. The area of each

10. The '069 patent is valid and enforceable.

11. All requirements under 35 U.S.C. § 287 have been satisfied with respect to the '069 patent.

12. Samsung has been and is infringing the '069 patent by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '069 patent, including but not limited to Samsung products bearing flat panel displays such as the Samsung netbook NP-N310-KA04US, notebook X460-41S, and HDTV UN32B6000.

13. Samsung has been and is continuing to induce infringement of the '069 patent under 35 U.S.C. § 271(b) and contributes to the infringement of the '069 patent under 35 U.S.C. § 271(c), in conjunction with such acts of making, using, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '069 patent. The infringing instrumentalities have no substantial non-infringing uses.

14. Samsung had and continues to have actual knowledge of the '069 patent and their coverage of Samsung's infringing instrumentalities, but has nonetheless engaged in the infringing conduct. Samsung's infringement of the '069 patent was and continues to be willful.

15. As a direct and proximate result of Samsung's acts of patent infringement, ITRI has been and continues to be injured and has sustained and will continue to sustain substantial damages.

light guiding surface **22** is shown in FIGS. **3** or **4**, namely, the middle of the transparent light guiding plate **2** serves as base and it is enlarged toward the two sides. The larger the diffusing area, the better the light diffusing effect for compensation the weak light region on the two sides. FIG. **5** shows that the diffusing unit **21** far away from the lateral light source has a large diffusing area and has a preferred diffusing effect so as to compensate the weak light region in the farther place. The diffusing units **21** on the front or rear surfaces of the transparent light guiding plate **2** have a convex (FIG. **6**) or a concave (FIGS. **3** and **5**) shapes. The elevation of the light guiding surface **22** is increased with the distance to the lateral light source **5**.

The diffusing units **21** on the FIGS. **3**, **5**, and **6** have a V shape lateral cross section. In FIGS. **3**, **5**, **6**, **7**, **8**, **9**, it is appreciated that the thickness of the transparent light guiding plate **2** is increased inversely proportional to the distance to the lateral light source **5** for reducing the light energy loss or the weight and volume thereof. FIGS. **10**, **11**, **12** show that the thickness from the front side to rear side of the transparent light guiding plate **2** is identical. FIGS. **8**, **9**, **11**, **12** show the thickness of the transparent light guiding plate **2**, wherein the two transverse sides have thickness wider than that in middle.

FIG. **3** shows that the light guiding surface **22** is in parallel with the lateral light source **5**. FIG. **13** shows that the light guiding surface **22** has an angle with the lateral light source. Clearly, in FIG. **13**, two sets of diffusing units are alternatively arranged with different angles and crossed over with each other to form a more uniform backlight effect.

As a result, the present invention has the following advantages:

1. The illumination of reflecting light in the front surface is enhanced, the loss is reduced and the average illumination of the backlight source device is improved.
2. The dark and light regions of the backlight source device are disappeared so that the backlight area is more uniform.
3. The backlight source device of the present invention is easily fabricated.

Although the present invention has been described using specified embodiment, the examples are meant to be illustrative and not restrictive. It is clear that many other variations would be possible without departing from the basic approach, demonstrated in the present invention. Therefore, all such variations are intended to be embraced within the scope of the invention as defined in the appended claims.

What is claimed is:

1. A backlight source device, comprising:

a transparent light guiding plate having front and rear surfaces;

a plurality of diffusing units installed on either the front surface or the rear surface of said transparent light guiding plate;

said diffusing units having respective light guiding surfaces with different areas which are extendedly and continuously arranged;

a diffusing piece on said transparent light guiding plate, said diffusing units are formed as two diffusing unit sets which are alternatively arranged on said transparent light guiding plate;

a reflecting piece below said transparent light guiding plate; and

a lateral light source.

2. The backlight source device as claimed in claim **1**, wherein said diffusing unit has a convex shape.

3. The backlight source device as claimed in claim **1**, wherein said diffusing unit has a concave shape.

4. The backlight source device as claimed in claim **1**, wherein said diffusing units are arranged with different distances therebetween.

5. The backlight source device as claimed in claim **1**, wherein said diffusing units each includes a lateral cross section with a V shape.

6. The backlight source device as claimed in claim **1**, wherein said diffusing units each includes a lateral cross section with a U shape.

7. The backlight source device as claimed in claim **1**, wherein said diffusing units each includes a projecting area and the projecting area of each of said diffusing units on said transparent light guiding plate is incremented as the distance from said lateral light source is increased.

8. The backlight source device as claimed in claim **1**, wherein said light guiding-surfaces of said diffusing units have different elevations which are respectively incremented as the distance from said lateral light source is increased.

9. The backlight source device as claimed in claim **1**, wherein said light guiding surface is parallel to said lateral light source.

10. The backlight source device as claimed in claim **1**, wherein said light guiding surface has an angle in alignment with the lateral light source.

11. The backlight source device as claimed in claim **1**, wherein said light guiding surfaces include projecting areas and the projecting areas of said light guiding surfaces increase as the distances from a middle portion of the light guiding plate is increased.

12. The backlight source device as claimed in claim **1**, wherein said transparent light guiding plate includes a thickness and the thickness of said transparent light guiding plate decreases from the distance to said lateral light source.

13. The backlight source device as claimed in claim **1**, wherein said transparent light guiding plate includes at least two side and the two sides of said transparent light guiding plate each has a thickness greater than that of a central portion of said transparent light guiding plate.

14. The backlight source device as claimed in claim **1**, wherein the lateral light source is a linear light source.

15. The backlight source device as claimed in claim **1**, wherein the lateral light source is a plurality of light sources arranged in one row.

* * * * *

EXHIBIT C

US006411357B1

(12) **United States Patent**
Ting et al.

(10) **Patent No.: US 6,411,357 B1**
(45) **Date of Patent: Jun. 25, 2002**

(54) **ELECTRODE STRUCTURE FOR A WIDE VIEWING ANGLE LIQUID CRYSTAL DISPLAY**

(75) Inventors: **Dai-Liang Ting**, Hsinchu; **Lisen Chuang**, Penghu; **Ching-Chao Chang**, Taipei, all of (TW)

(73) Assignee: **Industrial Technology Research Institute**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/483,416**

(22) Filed: **Jan. 14, 2000**

(30) **Foreign Application Priority Data**

Sep. 13, 1999 (TW) 88108187A01

(51) **Int. Cl.**[7] **G02F 1/1343**
(52) **U.S. Cl.** **349/141**; 349/146
(58) **Field of Search** 349/141, 143, 349/123, 146

(56) **References Cited**

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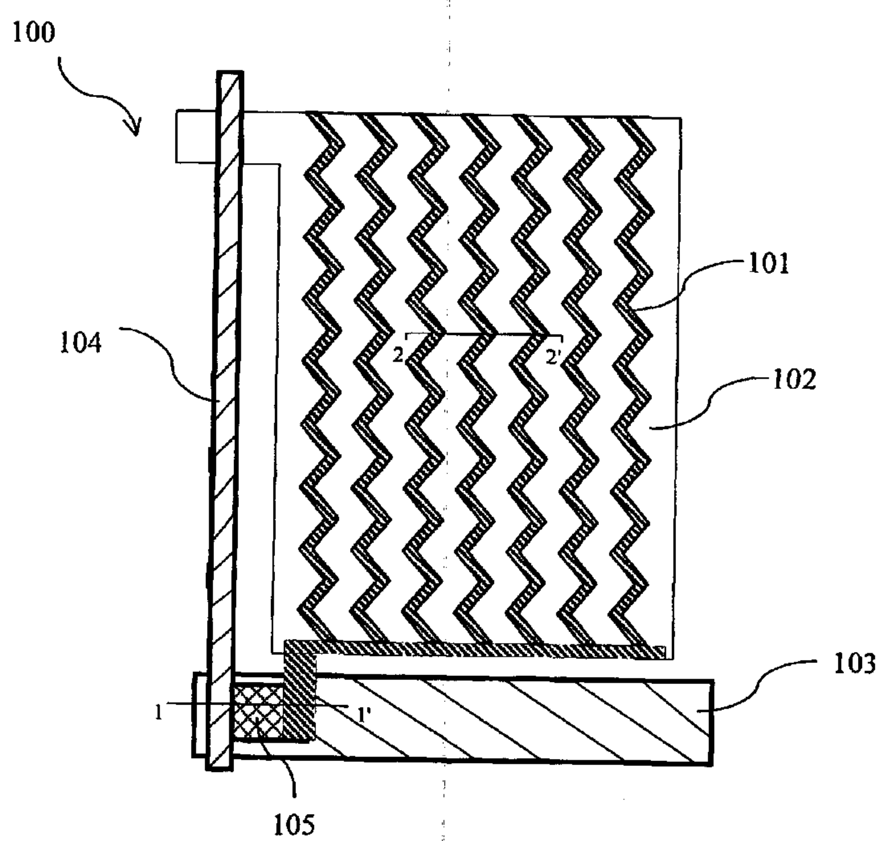
Primary Examiner—William L. Sikes
Assistant Examiner—Dung Nguyen

(57) **ABSTRACT**

An electrode structure for a liquid crystal display includes a layer of pixel electrodes each having a herringbone-shaped structure, a passivation layer and a layer of common electrodes. The pixel electrodes are formed in parallel above the common electrodes. The herringbone-shaped structure of a pixel electrode has a predefined turning angle between 45 degrees to 90 degrees. The pixel electrode structure allows the liquid crystals in the display to rotate in two directions, clockwise and counterclockwise, to compensate for the color dispersion caused by a wide viewing angle.

8 Claims, 4 Drawing Sheets



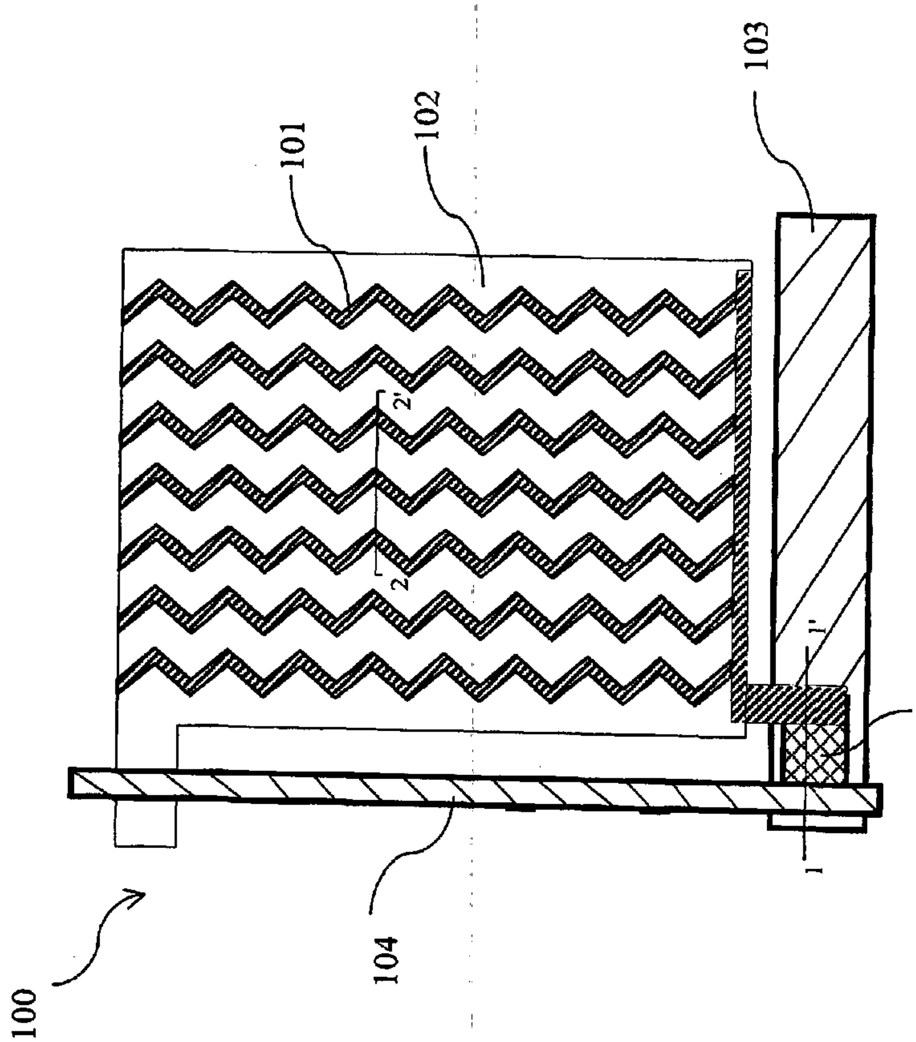


FIG. 1

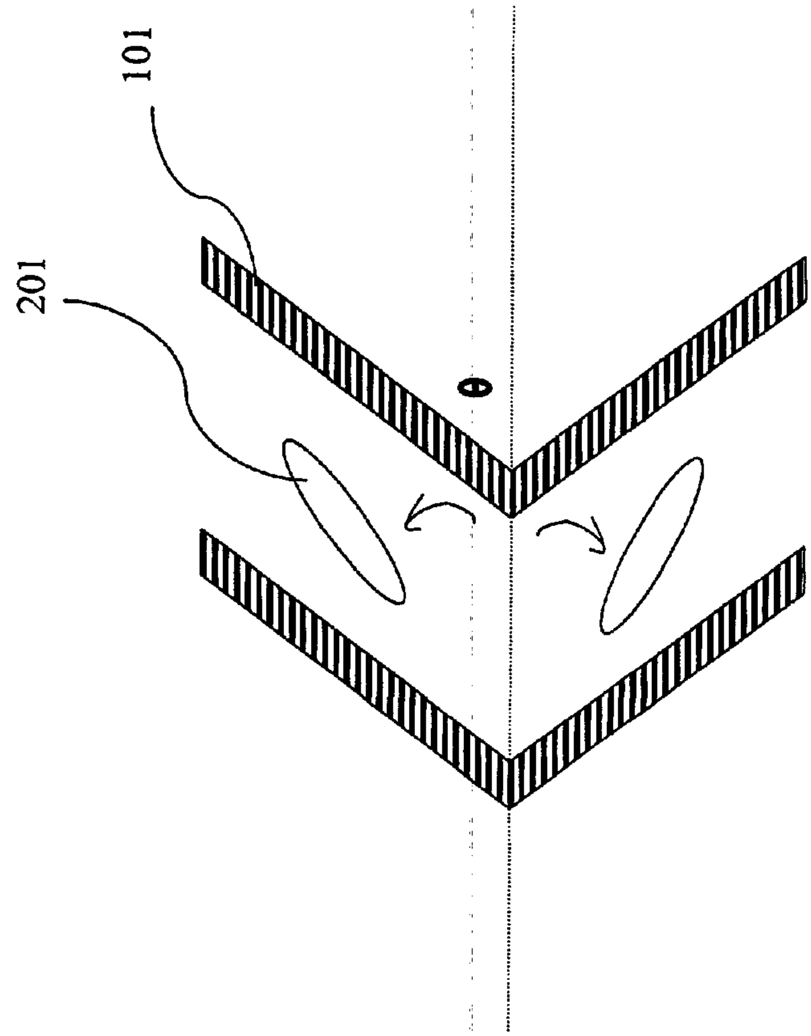


FIG. 2

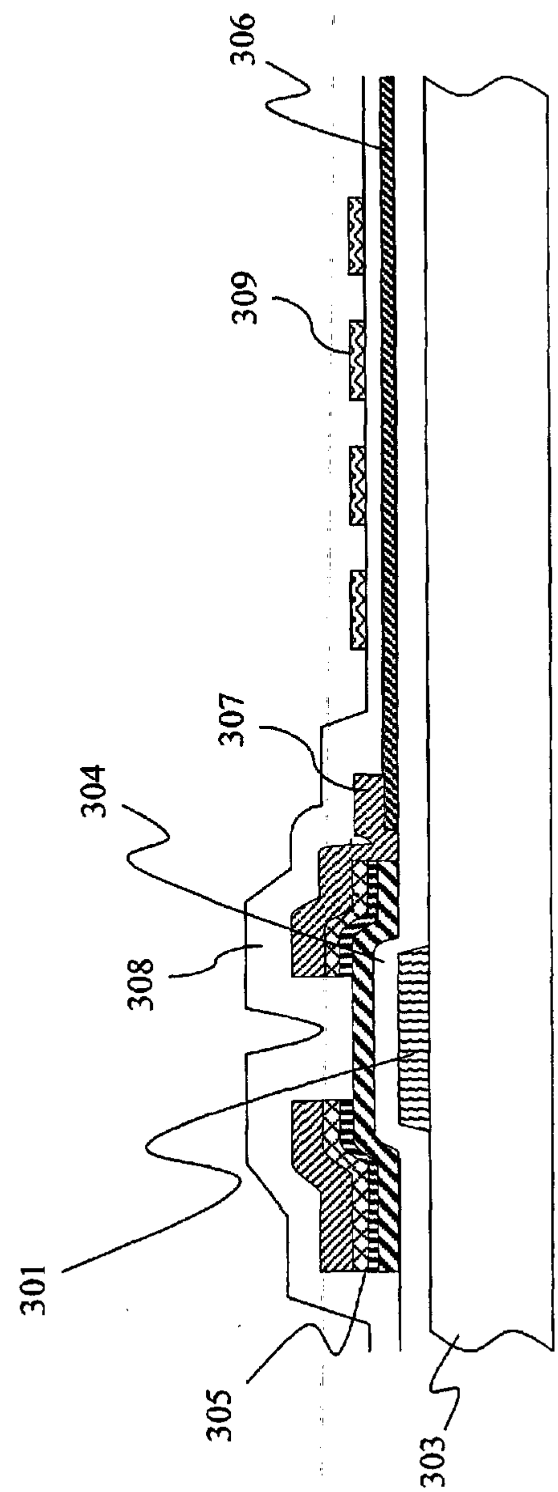


FIG. 3

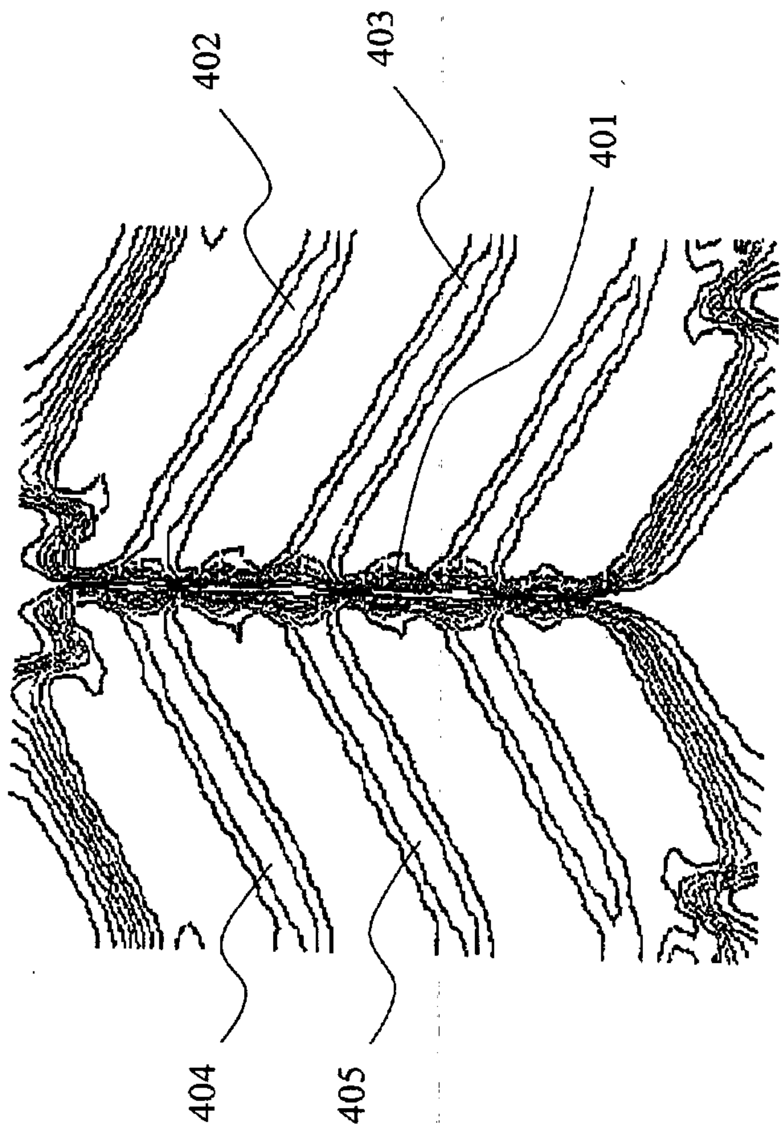


FIG. 4

ELECTRODE STRUCTURE FOR A WIDE VIEWING ANGLE LIQUID CRYSTAL DISPLAY

FIELD OF THE INVENTION

The present invention relates generally to an electrode structure of a liquid crystal display, and more particularly to an electrode structure of a wide viewing angle liquid crystal display.

BACKGROUND OF THE INVENTION

A large number of liquid crystal display (LCD) panels have recently been employed as display devices in electronic products. The technologies of wide viewing angle liquid crystal displays have been disclosed very often in recent years. In a Taiwan patent application No. 88108187 entitled "Electrode Structure of A Wide Viewing Angle Liquid Crystal Display", an electrode structure for providing wide viewing angle is disclosed. The electrode structure comprises an upper electrode layer having multiple comb-shaped and parallel conductors on a glass substrate, a lower electrode layer having a TN-type conductor and a layer of non-conductive insulator formed between the upper and lower electrode layers.

In the embodiment of the Taiwan patent application, the pixel electrodes in the upper layer of the electrode structure has a comb-shaped structure while the common electrode in the lower layer has a plate-shaped structure. A layer of negative-type liquid crystal is used to fill the space between the upper and lower glass substrates of the LCD. The two electrode layers are fabricated on the lower glass substrate.

The drawback of the electrode structure disclosed in the Taiwan patent application is that the liquid crystal driven by an electric voltage rotates toward one direction. Therefore, the effect of color dispersion at different viewing angle limits the viewing angle of the LCD and degrades the quality of the display.

SUMMARY OF THE INVENTION

The present invention has been made to overcome the above-mentioned drawback of the electrode structure in the prior art. The primary object of the invention is to provide an electrode structure for a wide viewing angle liquid crystal display. The electrode structure has upper and lower electrode layers. The pixel electrode in the upper layer has a herringbone-shaped structure while the common electrode in the lower layer has a plate-shaped structure.

The liquid crystal display has two separated glass substrates between which liquid crystals are filled. Multiple scan signal lines, multiple data signal lines, multiple switching elements, and a layer of common electrodes are fabricated on the surface of the lower glass substrate. The scan signal lines are perpendicular to the data signal lines in order to form a pixel matrix. A passivation layer made of a transparent non-conductive insulator is formed between the layer of pixel electrodes and the layer of common electrodes.

The herringbone-shaped structure of the pixel electrodes allows the liquid crystal molecules to rotate in two directions, clockwise and counterclockwise. The color dispersion caused by a wide viewing angle is thus compensated for. The herringbone-shaped structure also helps to maintain the brightness of pixels.

The foregoing and other objects, features, aspects and advantages of the present invention will become better understood from a careful reading of a detailed description provided herein below with appropriate reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a top view showing the electrode structure of a single pixel for a wide viewing angle liquid crystal display according to the preferred embodiment of the present invention.

FIG. **2** shows the liquid crystal rotates in two opposite directions according to the electrode structure of the present invention.

FIG. **3** shows the cross section along line **1–1'** and line **2–2'** of FIG. **1**.

FIG. **4** illustrates the brightness distribution in a single pixel of the electrode structure of the present invention when an electric voltage is applied.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** is a top view showing the electrode structure **100** of a single pixel for a wide viewing angle liquid crystal display according to the preferred embodiment of the present invention. Referring to FIG. **1**, the upper layer of the electrode structure **100** comprises a plurality of pixel electrodes **101** each having a herringbone-shaped structure while the lower layer comprises a common electrode **102** having a plate-shaped structure. The scan signal line region **103** is perpendicular to the data signal line region **104** to form a pixel.

As shown in FIG. **1**, a thin film transistor **105** used as a switching device is located near the crossing point of the scan signal line region **103** and the data signal line region **104** in a single pixel. The scan signal line region **103** and the data signal line region **104** are adjacent to the area where the pixel electrodes **101** are formed.

The thin film transistor is an active switching device that controls the charging and discharging of the pixel electrodes. In addition to the thin film transistor, the active switching device may also be a Metal Oxide Semiconductor (MOS) transistor, a diode, a Metal-Insulator-Metal (MIM) transistor or a variable resistor according to the invention.

The following illustrates in detail the electrode structure of a wide viewing angle liquid crystal display of the present invention. The electrode structure including a common electrode layer, a pixel electrode layer, and a passivation layer is formed above a glass substrate. On the top surface of the glass substrate, there are multiple scan signal lines, multiple data signal lines, multiple switching elements, and a layer of common electrodes. The passivation layer is made of a transparent non-conductive insulator and located between the common electrode layer and the pixel electrode layer. The passivation layer can be formed by depositing or growing an insulator film on the thin film transistor.

For every single pixel, the data signal line is located above and perpendicular to the scan signal line. At least a switching element such as a thin film transistor **105** is fabricated near the crossing point of the scan signal line and the data signal line. The gate terminal of the switching element connects to the scan signal line, the drain terminal connects to the data signal line and the source terminal connects to the pixel electrode.

As mentioned above, the pixel electrode has a herringbone-shaped structure. Pixel electrodes are formed in parallel. The turning angle θ shown in FIG. **2** in the herringbone-shaped structure is within a pre-defined range,

about 45 to 90 degrees. The herringbone-shaped structure of the pixel electrodes allows the liquid crystal molecules **201** to rotate in two directions, clockwise and counterclockwise. As shown in FIG. **2**, the liquid crystal molecules **201** rotates in both clockwise and counterclockwise directions by a Ø angle. The color dispersion-caused by a viewing angle is thus compensated for and the effect of color dispersion is reduced.

The herringbone-shaped structure of the pixel electrodes maintains the brightness above the pixel electrodes in the certain range of Ø. The intensity is proportional to the square of sin 2Ø, therefore, if the turning angle θ is less than 45 degrees, the maximal value of Ø is also less than 45 degrees. The pixel brightness will not reach its maximum value.

According to the invention, the electrode pitch in the layer of pixel electrodes is about 1 to 15 μm and the electrode width is about 1 to 10 μm. In the structure of a single pixel, the herringbone-shaped pixel electrodes **101** and the common electrode **102** both keep a distance from the scan signal line region **103** and the data signal line. region **104**. They do not cross over the scan signal line region **103** and the data signal line region **104**.

FIG. **3** shows the cross section along line **1–1'** and line **2–2'** of FIG. **1**. Along line **1–1'** of FIG. **1** is the steps of fabricating the thin film transistor, the data line and the scan line. Along line **2–2'** is the steps of fabricating the pixel electrodes **101** and the common electrode **102**.

Referring to FIG. **3**, the cross section along line **1–1'** of FIG. **1** illustrates in detail every layer of the structure above the substrate. A metallic layer of the scan signal line **301** is first formed above the glass substrate **303**. Then, the glass substrate **303** is covered with an insulator layer **304** and an island-like region **305** is formed to provide an active layer for the thin film transistor. The thin film transistor comprises at least a gate, a drain, and a source. The gate terminal of the thin film transistor connects to the scan signal line **301**, the drain terminal connects to the data signal line **307** and the source terminal connects to the pixel electrodes **306**.

The present invention forms a layer of plate-shaped common electrodes **306**. The plate-shaped common electrodes **306** can be made of transparent or non-transparent conductive materials. The general transparent conductive materials may be indium-tin-oxide (ITO), SnO_2, N type amorphous silicon film, N type poly-silicon film, P type poly-silicon film, and ZnO, etc. Non-transparent conductive material may be other metallic material. The plate-shaped common electrodes **306** do not cross over the island-like region **305**, as shown in FIG. **3**.

Above the island-like region **305** is a metallic layer of data signal lines **307**. A passivation layer **308** is further used to cover the substrate. Similarly, the electric contact with the data signal line metallic layer **307** can be established by forming multiple contact holes outside the pixel region.

Along line **2–2'** of FIG. **1** is the steps of forming the layer of pixel electrodes. A layer of herringbone-shaped pixel electrodes **309** is fabricated above the layer of common electrodes **306** and the passivation layer **308**. The herringbone-shaped pixel electrodes **309** can be made of transparent or non-transparent conductive materials.

As mentioned above, the structure of the herringbone-shaped pixel electrodes preserves the brightness of pixels.

FIG. **4** illustrates the distribution of brightness in a single pixel of the electrode structure of the present invention when an electric voltage is applied. The brightness at the middle portion **401** of the herringbone-shaped pixel electrode is almost zero. However, more than 70% effective transmission of light can be achieved at regions **402, 403**, **404**, and **405** that are parallel to each other.

Although this invention has been described with a certain degree of particularity, it is to be understood that the present disclosure has been made by way of preferred embodiments only and that numerous changes in the detailed structure and combination as well as arrangement of parts may be restored to without departing from the spirit and scope of the invention as hereinafter set forth.

What is claimed is:

1. An electrode structure of a wide viewing angle liquid crystal display comprising:

a scan signal line;

a data signal line perpendicular to said scan signal line, said scan signal line and said data signal line defining a pixel area;

a common electrode in said pixel area;

a passivation layer above said common electrode; and

a plurality of pixel electrodes each having a herringbone-shaped structure and running substantially in parallel with said data signal line above said passiviation layer and said common electrode;

wherein said common electrode has a plate-shaped structure substantially filling said pixel area below said plurality of pixel electrodes.

2. The electrode structure of a wide viewing angle liquid crystal display as claimed in claim **1**, said herringbone-shaped structure having a turning angle ranging from 45 degrees to 90 degrees.

3. The electrode structure of a wide viewing angle liquid crystal display as claimed in claim **1**, said plurality of pixel electrodes having a pitch ranging from 1 to 15 μm and the width of each pixel electrode ranging from 1 to 10 μm.

4. The electrode structure of a wide viewing angle liquid crystal display as claimed in claim **1**, wherein said common electrode is made of indium-tin-oxide, SnO_2, N-type amorphous silicon film, N type poly-silicon film, P type poly-silicon film, or ZnO.

5. The electrode structure of a wide viewing angle liquid crystal display as claimed in claim **1**, wherein said pixel electrodes are made of indium-tin-oxide, SnO_2, N-type amorphous silicon film, N type poly-silicon film, P type poly-silicon film, or ZnO.

6. The electrode structure of a wide viewing angle liquid crystal display as claimed in claim **1**, wherein said pixel electrodes are made of metal material.

7. The electrode structure of a wide viewing angle liquid crystal display as claimed in claim **1**, further comprising a switching device.

8. The electrode structure of a wide viewing angle liquid crystal display as claimed in claim **7**, said switching device being a thin film transistor.

* * * * *

EXHIBIT D

16. Unless Samsung is enjoined by this Court from continuing their infringement of the '069 patent, ITRI will suffer additional irreparable harm and impairment of the value of its patent rights.

17. ITRI has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and ITRI is entitled to recover its reasonable and necessary attorneys' fees, costs, and expenses.

IV. INFRINGEMENT OF U.S. PATENT NO. 6,164,791

18. On December 26, 2000, the USPTO issued U.S. Patent No. 6,164,791, entitled "Backlight Source Device" (hereinafter "the '791 patent"). A true and correct copy of the '791 patent is attached hereto as Exhibit B.

19. ITRI is the owner of all right, title, and interest in and to the '791 patent by assignment, with full right to bring suit to enforce the patent, including the right to recover for past infringement damages and the right to recover future royalties, damages, and income.

20. The '791 patent is valid and enforceable.

21. All requirements under 35 U.S.C. § 287 have been satisfied with respect to the '791 patent.

22. Samsung has been and is infringing the '791 patent by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '791 patent, including but not limited to Samsung products bearing flat panel displays such as the Samsung netbook NP-N310-KA04US, notebook X460-41S, and HDTV UN32B6000.

US006768526B2

(12) **United States Patent** (10) **Patent No.: US 6,768,526 B2**
Ho et al. (45) **Date of Patent: Jul. 27, 2004**

(54) TIME-SEQUENTIAL COLOR SEPARATOR AND LIQUID CRYSTAL PROJECTOR USING THE SAME

(75) Inventors: **Fang-Chuan Ho**, Hsinchu (TW); **Lai-Chang Lin**, Taipei Hsien (TW)

(73) Assignee: **Industrial Technology Research Institute** (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 239 days.

(21) Appl. No.: **09/871,618**

(22) Filed: **Jun. 4, 2001**

(65) **Prior Publication Data**

US 2002/0080304 A1 Jun. 27, 2002

(30) **Foreign Application Priority Data**

Dec. 21, 2000 (TW) .... 89127527 A

(51) **Int. Cl.**[7] **G02F 1/1347**

(52) **U.S. Cl.** **349/74**; 349/96; 349/97; 349/117; 349/119; 349/80; 349/100; 349/9; 353/20; 353/31; 353/33; 353/34; 353/37; 353/84

(58) **Field of Search** 349/57, 77, 34, 349/8, 172, 74, 75; 359/634, 245, 246

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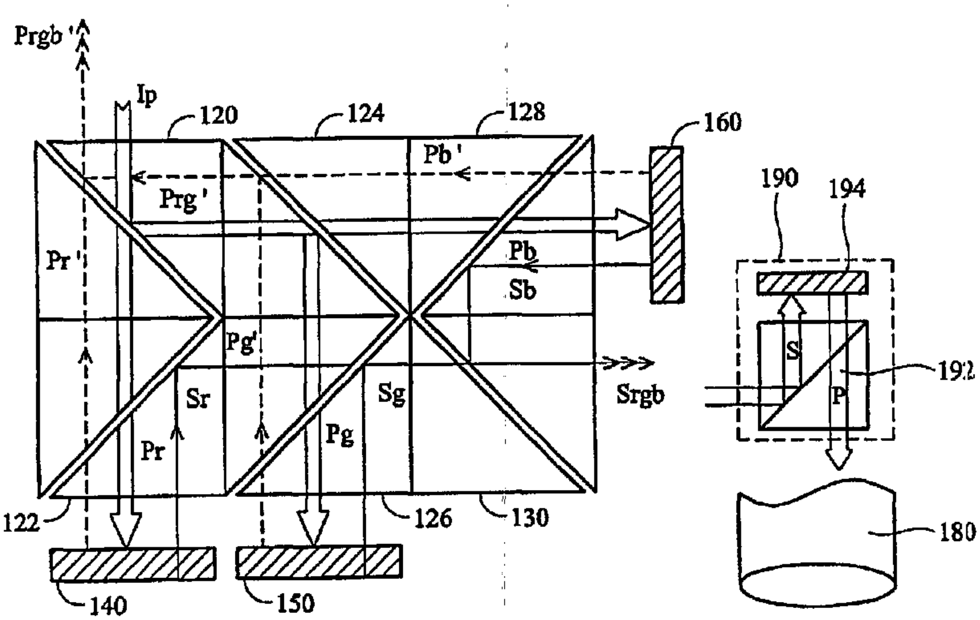
Primary Examiner—Nathan J. Flynn
Assistant Examiner—Fazli Erdem
(74) *Attorney, Agent, or Firm*—Birch, Stewart, Kolasch & Birch, LLP

(57) **ABSTRACT**

A fast time-sequential color separator that can fast-switch to output various wavelength ranges of lights having high color purity and a high contrast ratio, which includes: a prism module to separate an incident light into various wavelength ranges of light beams which are emitted from various prisms of the prism module; a plurality of ferroelectric liquid crystal panels, respectively placed on emerging surfaces of the various wavelength ranges of light beams, to reflect the various wavelength ranges of light beams to the prism module; and a power supply, respectively connected to the plurality of ferroelectric liquid crystal panels, to fast-switch the liquid crystal panels, respectively, to sequentially emit the various wavelength ranges of light beams from the prism module. Furthermore, a full color LCD projector can be constructed by the color separator, a transmissive or reflective fast response display element such as a liquid crystal light valve, and other elements such as micro-mirrors, etc.

18 Claims, 9 Drawing Sheets



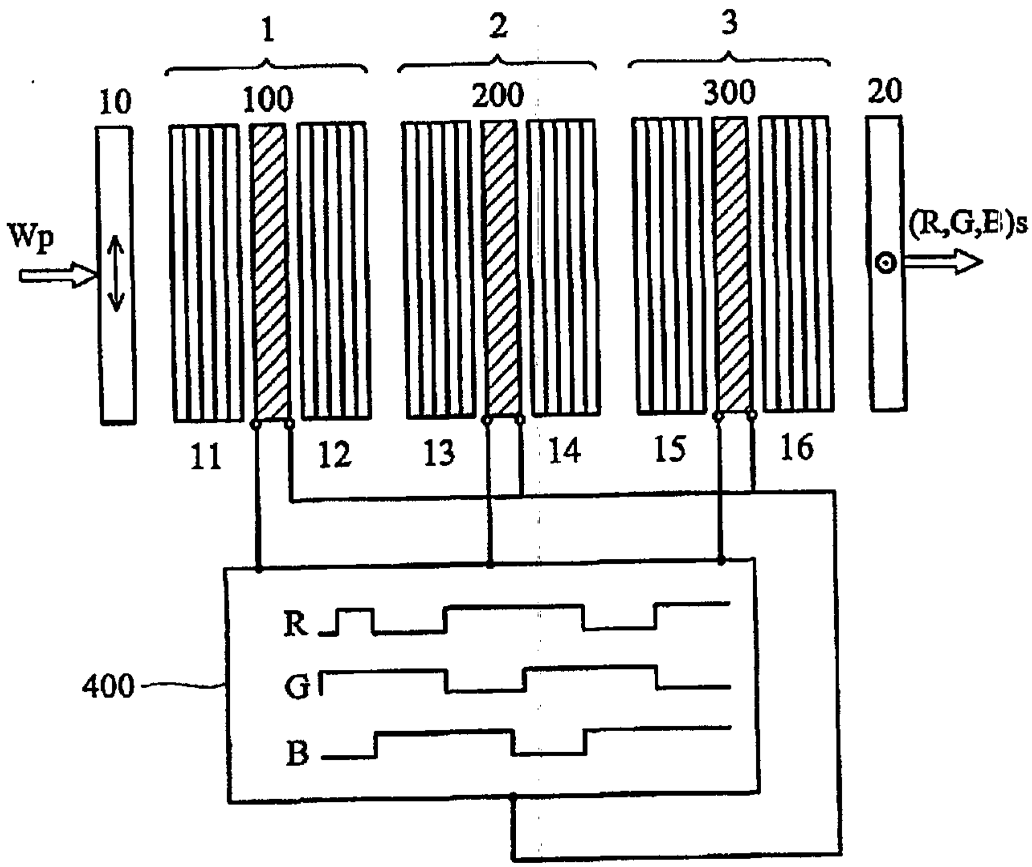


FIG. 1

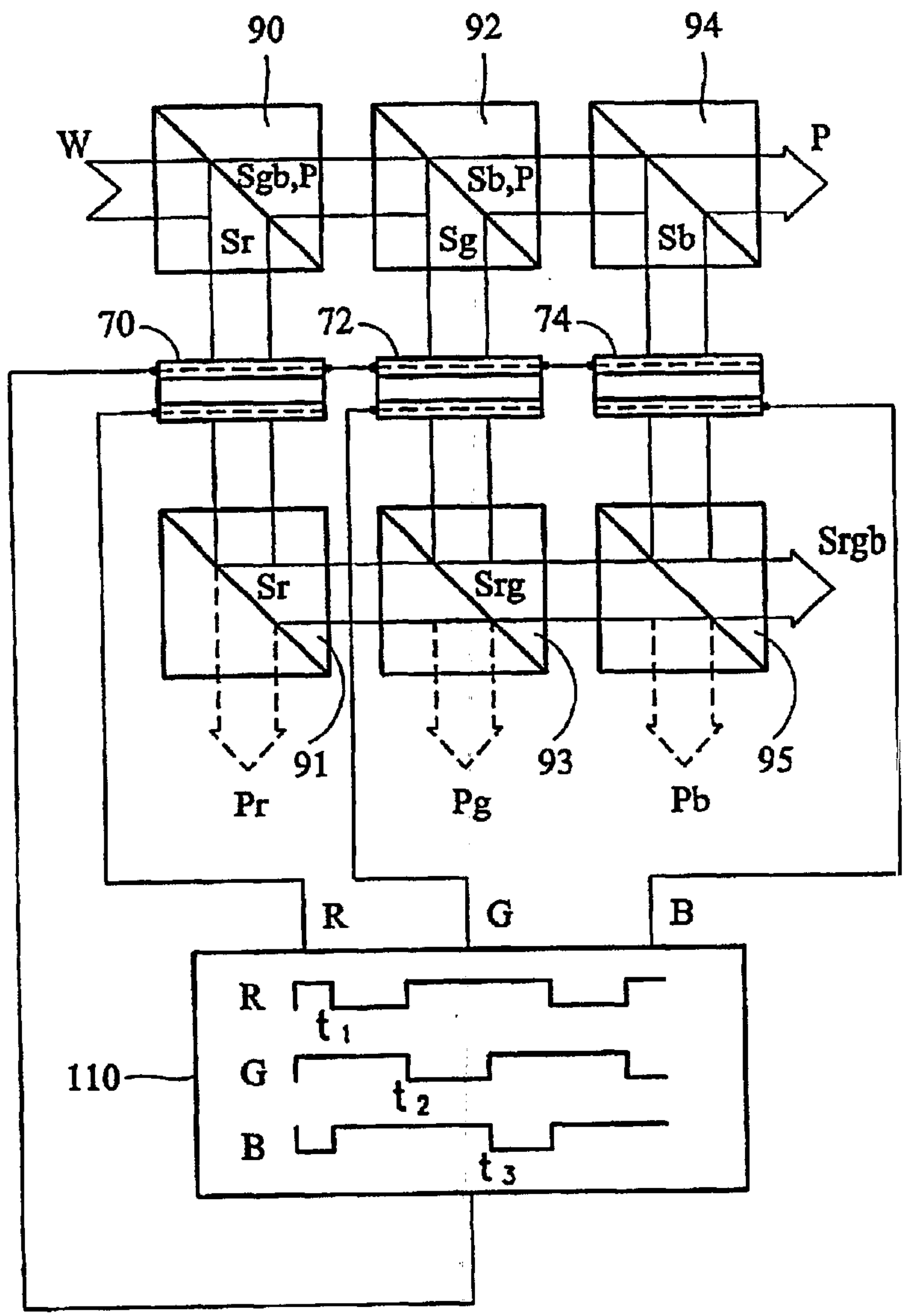

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FIG. 2

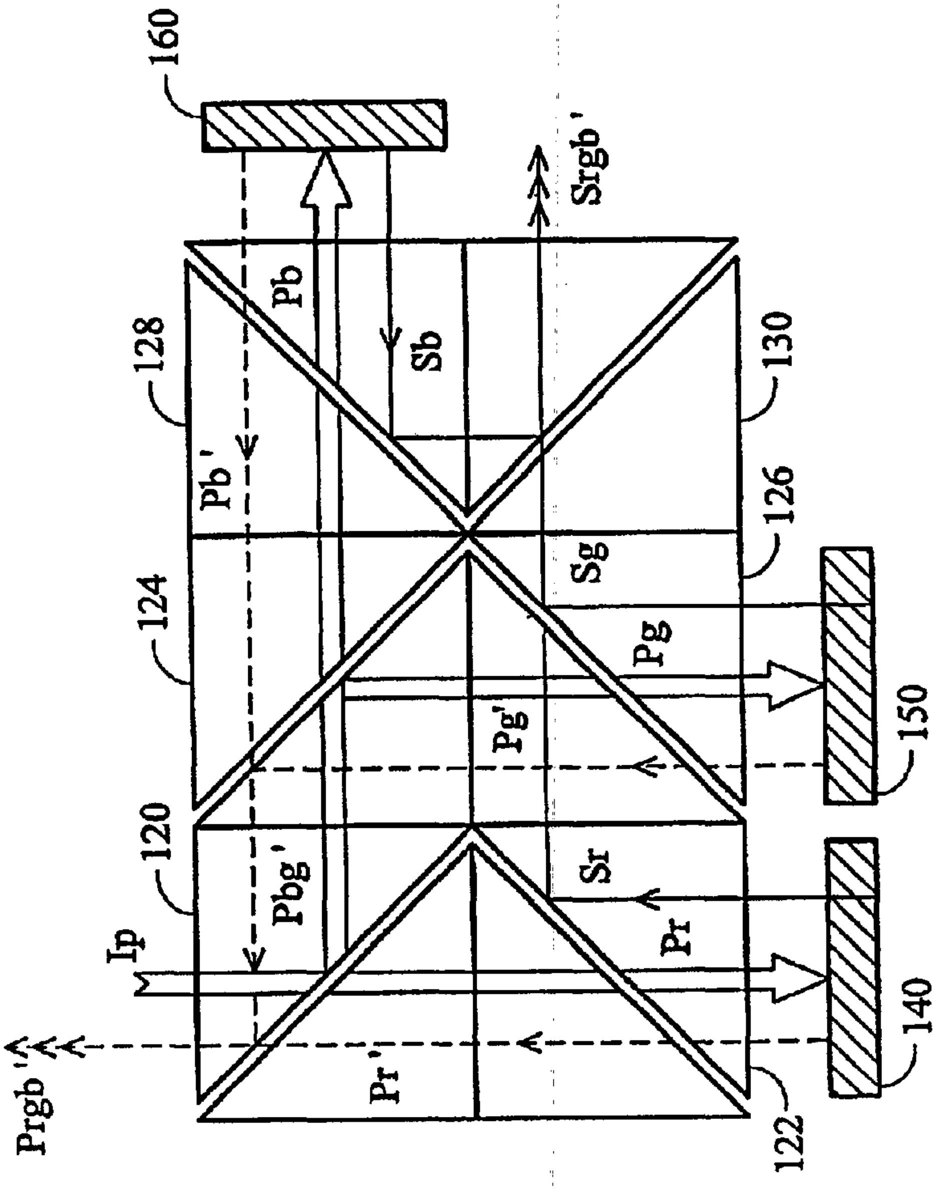
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FIG. 3

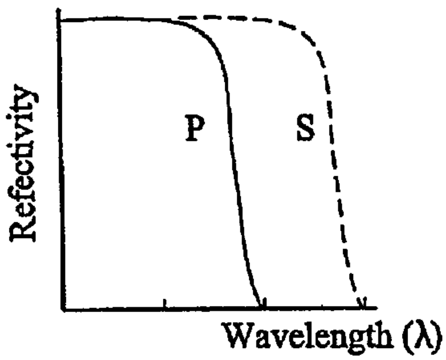

FIG. 4A

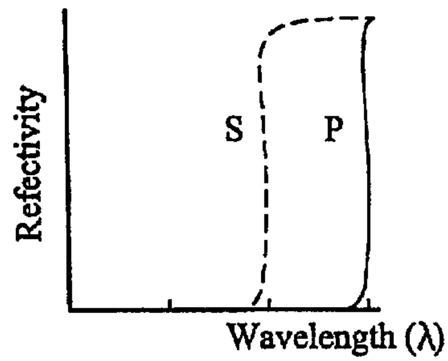

FIG. 4B

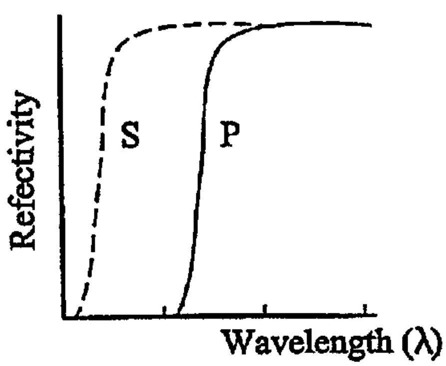

FIG. 4C

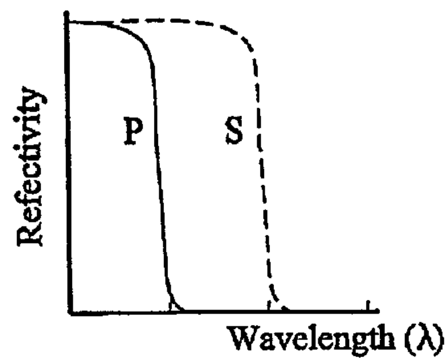

FIG. 4D

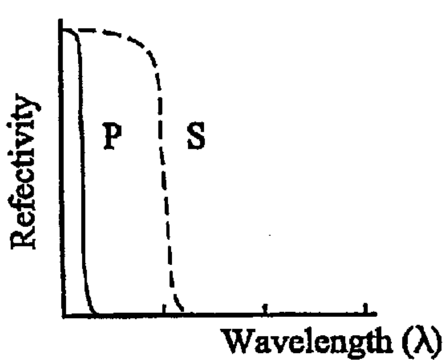

FIG. 4E

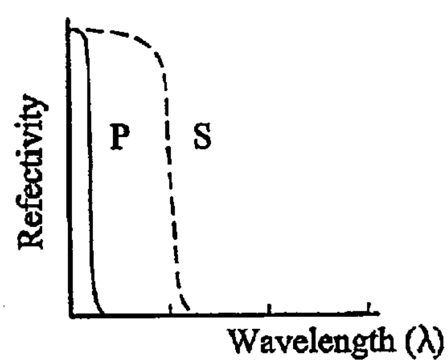

FIG. 4F

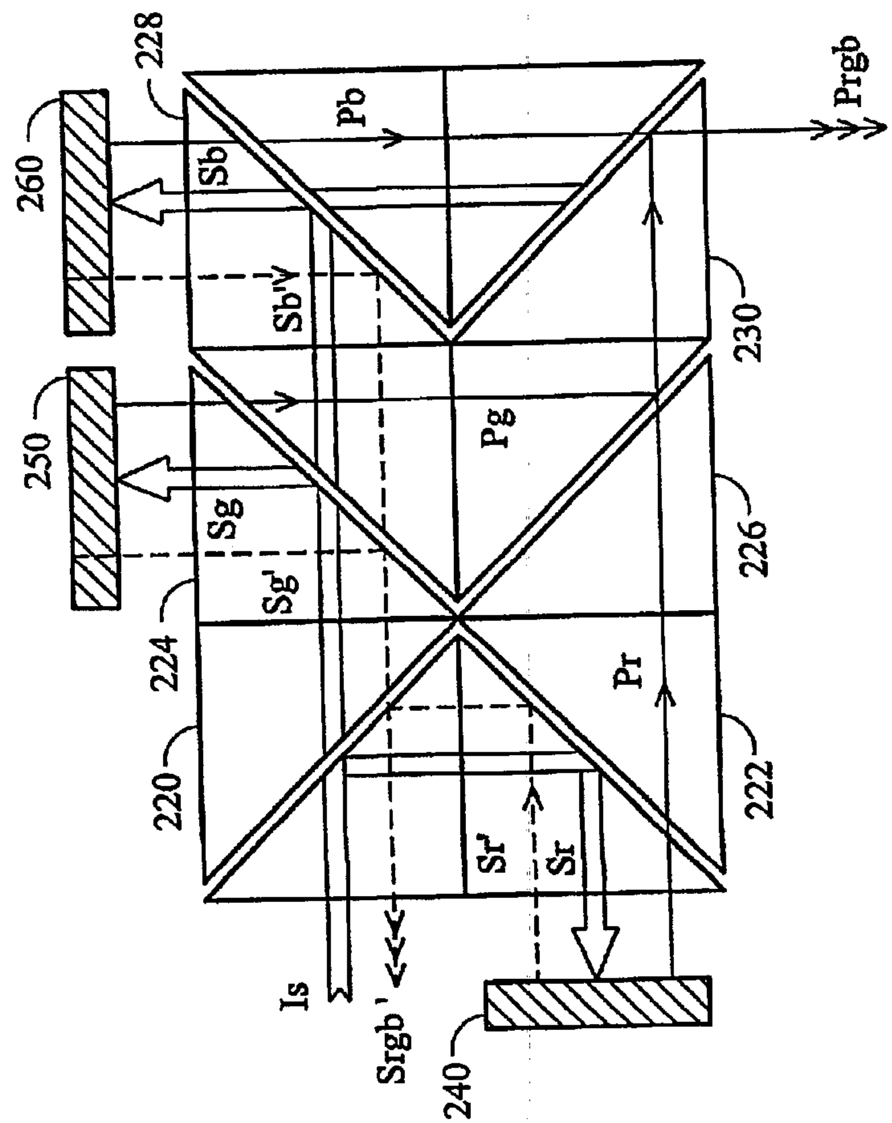
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FIG. 5

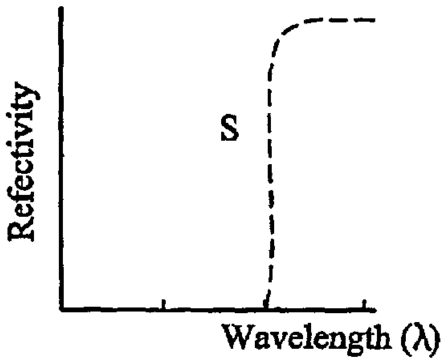


FIG. 6A

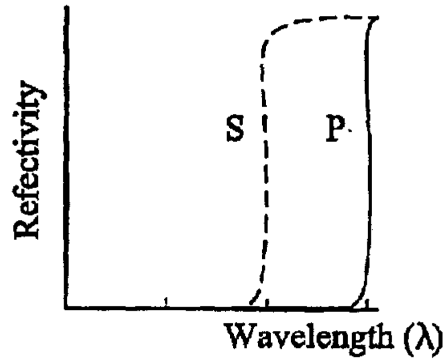


FIG. 6B

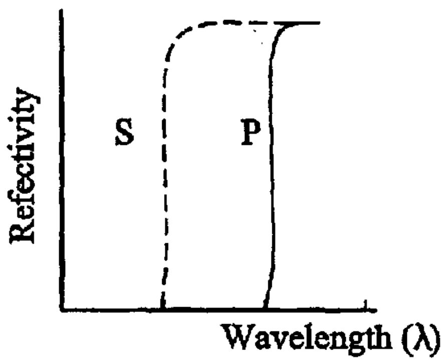


FIG. 6C

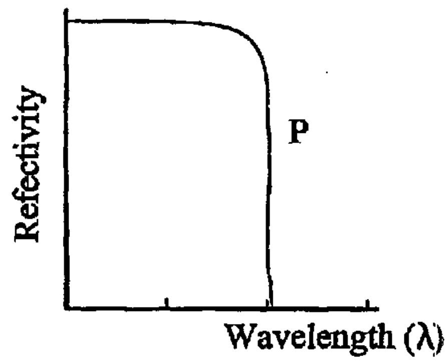


FIG. 6D

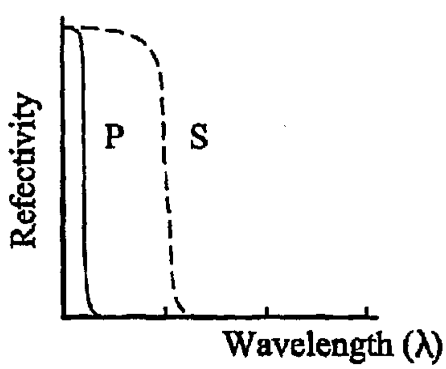


FIG. 6E

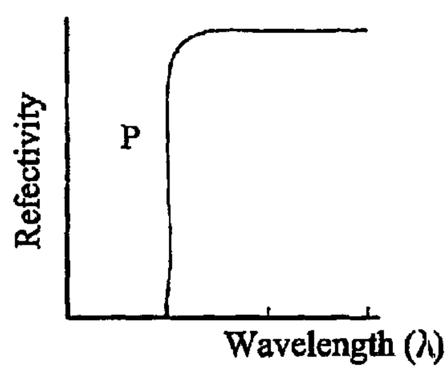
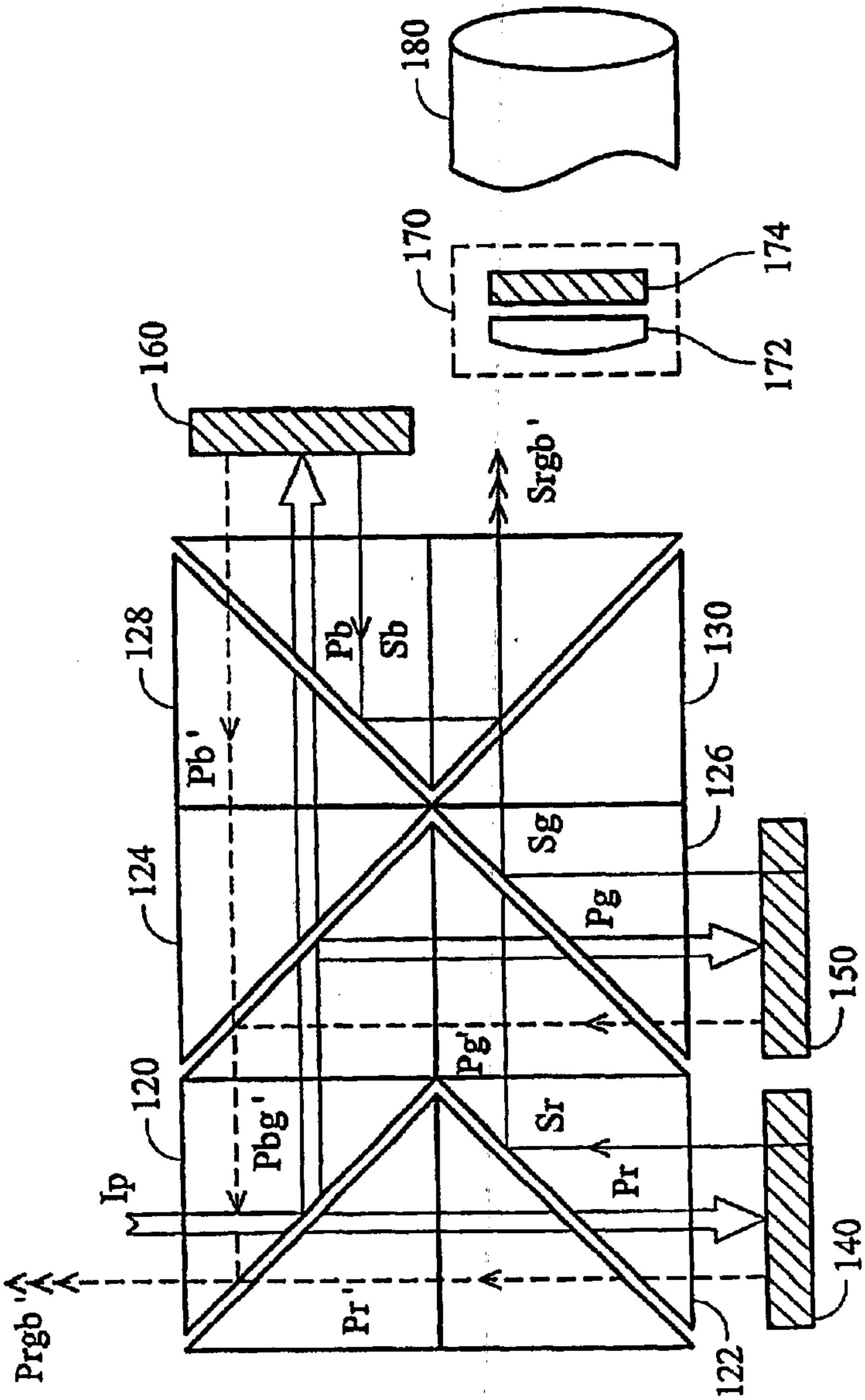


FIG. 6F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Pr'
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FIG. 7

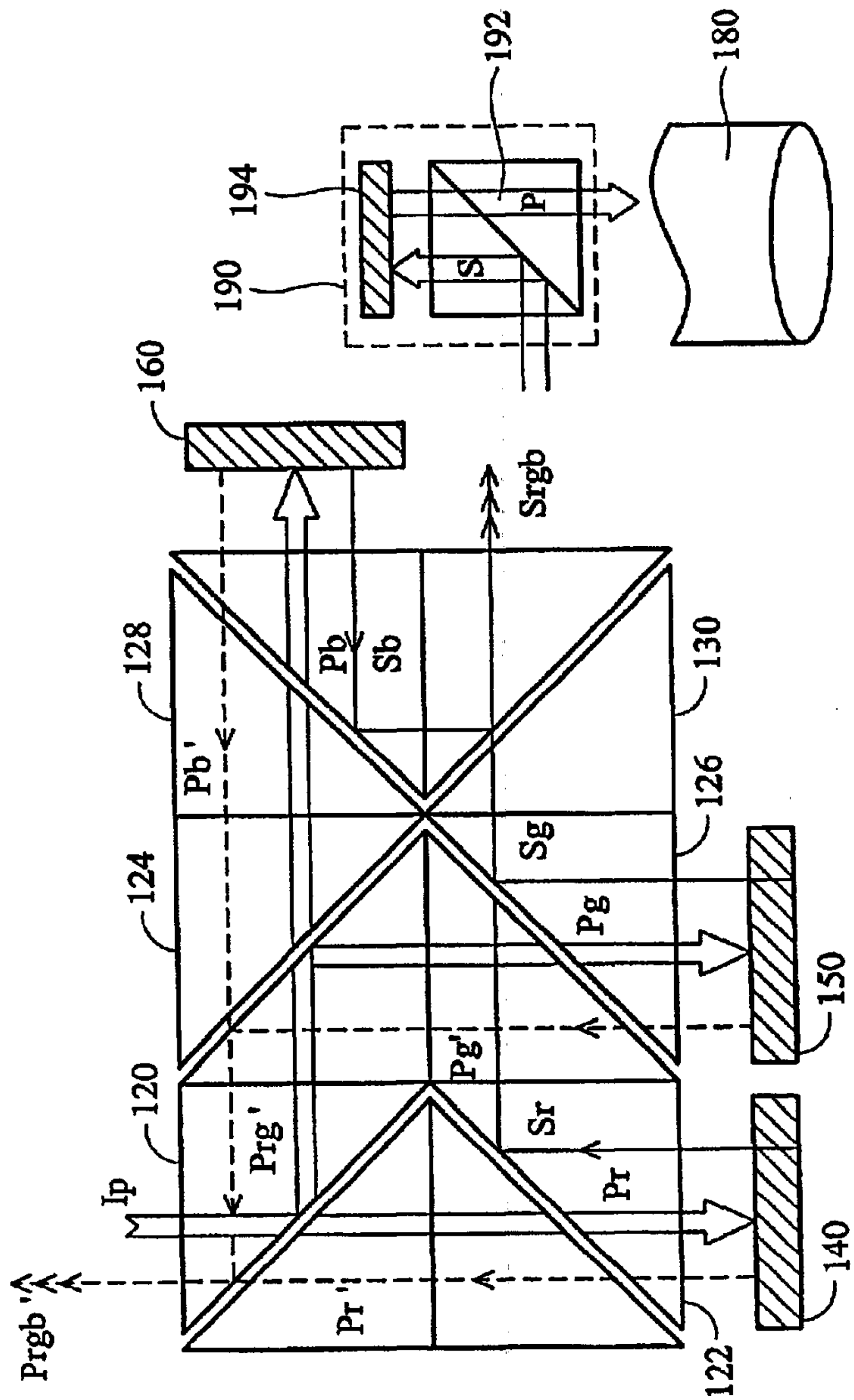
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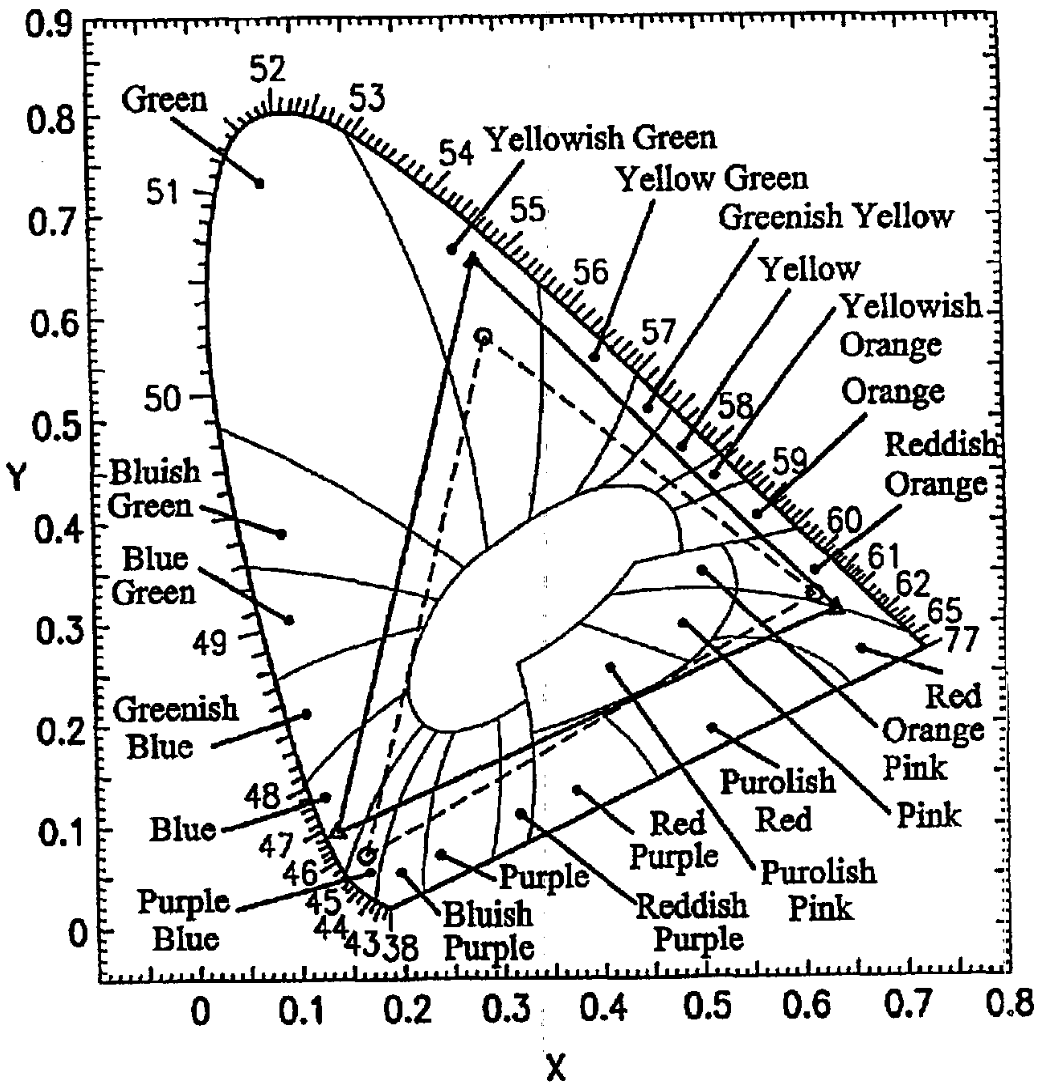
FIG. 8



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0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Y
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0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
X
52
53
54
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56
57
58
59
60
61
62
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77
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Blue Green
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Blue
Purple Blue
Bluish Purple
Purple
Reddish Purple
Red Purple
Purolish Red
Purolish Pink
Pink
Orange Pink
Red

FIG. 9

23. Samsung has been and is continuing to induce infringement of the '791 patent under 35 U.S.C. § 271(b) and contributes to the infringement of the '791 patent under 35 U.S.C. § 271(c), in conjunction with such acts of making, using, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '791 patent. The infringing instrumentalities have no substantial non-infringing uses.

24. Samsung had and continues to have actual knowledge of the '791 patent and their coverage of Samsung's infringing instrumentalities, but has nonetheless engaged in the infringing conduct. Samsung's infringement of the '791 patent was and continues to be willful.

25. As a direct and proximate result of Samsung's acts of patent infringement, ITRI has been and continues to be injured and has sustained and will continue to sustain substantial damages.

26. Unless Samsung is enjoined by this Court from continuing their infringement of the '791 patent, ITRI will suffer additional irreparable harm and impairment of the value of its patent rights.

27. ITRI has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and ITRI is entitled to recover its reasonable and necessary attorneys' fees, costs, and expenses.

TIME-SEQUENTIAL COLOR SEPARATOR AND LIQUID CRYSTAL PROJECTOR USING THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a color separator, especially to a time-sequential color separator and a liquid crystal projector including the color separator.

2. Description of the Related Art

Conventional color separators are normally classified into mechanical type and electronic type. The former uses various color filters to mechanically separate color lights from an incident white light. Such a mechanical type color separator normally has a complex structure, a big volume and all of the drawbacks due to mechanical movement. The latter is constructed by electronic circuits and light valves. Therefore the quality of an electronic type color separator is related to the response speed of light valve, the transmittance, the color purity and the contrast ratio.

A conventional electronic type color separator as disclosed in U.S. Pat. No. 4,232,948 by Shanks uses a liquid crystal light valve, which can change the polarization of a light passing therethrough, and a retarder having a birefringence effect to change the observed color of the light passing through the device. The transmittance, the switching speed and the color purity obtained by such a color separator is not desirable. Furthermore, in U.S. Pat. No. 5,347,378, Handschy et al. utilize a structure which combines a color-selective filter with a fast-switching liquid crystal light valve. However, the transmittance and the color purity obtained by the color separator are still not satisfactory.

Accordingly, in "High Brightness Saturated Color Shutter Technology," SID Symposium, Vol. 27, p.411, 1996 by Sharp and Johnson and "Retarder Stack Technology for Color Manipulation," SID, 1999, by G. D. Sharp and T. R. Brige, a time-sequential three primary color switch having a high response speed and a saturated chromaticity, which combines a polarization retarder stack (PRS) and a fast-switching liquid crystal light valve, is disclosed. The device disclosed in U.S. Pat. No. 5,751,380 was developed by ColorLink, Inc., as a commercial product known as "ColorSwitch α". The relevant description can be referred to in "High Throughput Color Switch for Sequential Color Projector," SID 2000 Digest, p.96, 2000, by G. B. Sharp, et al.

FIG. 1 illustrates the structure of the color switch disclosed by G. B. Sharp, in which the reference numeral **10** and **20** respectively represent visible light polarizer, the reference numeral **1, 2, 3** respectively represent light valve units of red color, green color and blue color. The red-color light valve unit **1** includes a ferroelectric liquid crystal (FLC) panel **100**, a front PRS **11** and a rear PRS **12**. The green-color light valve unit **2** includes an FLC panel **200**, a front PRS **13** and a rear PRS **14**. The blue-color light valve unit **3** includes an FLC panel **300**, a front PRS **15** and a rear PRS **16**. A time-sequential pulse **400** is respectively connected to the FLC panels **100**, **200** and **300** to emit the polarized red light, green light and blue light in sequence.

Refer to FIG. **2**, which is relevant prior art disclosed by the inventor and filed as a patent application entitled as "FIELD SEQUENTIAL COLOR PROJECTION DISPLAY", whose application No. is 09/524,051. In this prior art, the dichroic prisms **90~95** are used for color separation and recombination. The three FLC panels **70, 72** and **74** are controlled by a time-sequential pulse **110** to emit the light beams of red color, green color and blue color in sequence. The switching speed of the field sequential color projection display system can achieve 0.05 msec. Furthermore, there is substantially no energy loss for the light beams of three primary colors since the system is constructed by dielectric interference filters. However, the alignment of this prior-art system is difficult.

The drawback of the above-described prior arts using FLC panels is the limitation of contrast ratio when a light beam passes through the FLC panel. Therefore, in order to overcome the shortcomings of the prior art, it is important to increase the contrast ratio of the light valve, as well as the response speed of the FLC panel.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a fast time-sequential color separator that can be fast switched to output various wavelength ranges of lights having high color purity and high contrast ratio.

A full color LCD projector can be constructed by the color separator, a transmissive or reflective fast-response display element such as a liquid crystal light valve, and other elements such as micro-mirrors, etc.

This invention takes advantage of non-absorption of the interference polarizer and large aperture ratio, high contrast ratio and fast response speed of the reflective ferroelectric liquid crystal panel to constitute a three primary color separator. The polarized incident white light is separated into the light beams of three primary colors by the color filters. A time-sequentially-controlled single-pixel reflective FLC panel then sequentially reflects the color light beams to a single panel of FLC display. The frame frequency of the FLC display can be larger than 0.15 MHz. The CIE coordinates of the three primary colors obtained by the color separator of this invention are (x=0.65, y=0.31), (x=0.28, y=0.69) and (x=0.12, y=0.09), respectively.

Further scope of the applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention bill become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can be more fully understood by reading the subsequent detailed description in conjunction with the examples and references made to the accompanying drawings, which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

FIG. **1** is a diagram illustrating a prior-art color separator;

FIG. **2** is a diagram illustrating another prior-art color separator;

FIG. **3** is a diagram illustrating a color separator according to one embodiment of this invention;

FIGS. **4A** to **4F** are spectral diagrams of the dichroic filters in the prisms of FIG. **3**;

FIG. **5** is a diagram illustrating a color separator according to another embodiment of this invention;

FIG. **6A** to **6F** are spectral diagrams of the dichroic filters in the prisms of FIG. **5**;

FIG. 7 is a diagram illustrating a liquid crystal projector including the color separator of this invention;

FIG. 8 is a diagram illustrating another liquid crystal projector including the color separator of this invention; and

FIG. 9 illustrates the CIE coordinates for the light beams of three primary colors obtained by using the color separator of this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 3, this invention includes a prism module that is constructed by six dichroic prisms **120**, **122**, **124**, **126**, **128** and **130**, that separate an incident light into various wavelength ranges of light beams which are emitted from various prisms of the prism module; ferroelectric liquid crystal panels **140**, **150** and **160**, respectively placed on emerging surfaces of the various wavelength ranges of light beams, for reflecting the various wavelength ranges of light beams to the prism module; and a power supply, respectively connected to the ferroelectric liquid crystal panels **140**, **150** and **160**, for fast-switching the liquid crystal panels, respectively, to sequentially emit the various wavelength ranges of light beams from the prism module. The spectrum of the dichroic prism **120** is as shown in FIG. 4A. The spectrum of the dichroic prism **122** is as shown in FIG. 4B. The spectrum of the dichroic prism **124** is as shown in FIG. 4C. The spectrum of the dichroic prism **126** is as shown in FIG. 4D. The spectrum of the dichroic prism **128** is as shown in FIG. 4E. The spectrum of the dichroic prism **130** is as shown in FIG. 4F.

When a parallel-polarized white light is incident to the prism module, the red component Pr of the parallel-polarized white light passes through the prisms **120** and **122** and is incident to the FLC panel **140**. When the FLC panel **140** is switch-on, the parallel-polarized red light Pr (indicated by solid line in the drawing) is reflected and converts into a vertical-polarized red light Sr, which is then reflected by the prism **122** to pass through the prisms **126** and **130** and emerges from the prism **130**. When the FLC panel **140** is switch-off, the polarization of the parallel-polarized red light Pr is not changed, the parallel-polarized red light Pr is reflected by the FLC panel **140** to pass through the prisms **122** and **120**. The reflected parallel-polarized red light Pr' emerges from the prism module along the incident optical path.

The green component Pg and the blue component Pb of the parallelly polarized white light is directed toward the prism **124** after it is reflected by the prism **120**. The parallelly polarized green light Pg is reflected by the prism **124** to pass through the prism **126** and is then incident to the FLC panel **150**. When the FLC panel **150** is switch-on, the parallel-polarized green light Pg is converted to a vertical-polarized green light Sg, which is reflected by prism **126** and emerges from the prism **130**. When the FLC panel **150** is switch-off, the parallel-polarized green light Pg is reflected and maintains its polarization. The reflected parallel-polarized green light Pg' passes through the prism **126** and is sequentially reflected by the prisms **124** and **120** and emerges from the prism module.

The blue component Pb of the parallel-polarized white light is reflected by the prism **120** to pass through the prisms **124** and **128**, and then incident to the FLC panel **160**. When the FLC panel **160** is switch-on, the parallel-polarized blue light Pb is reflected by the FLC panel **160** and is converted to a vertically polarized blue light Sb, which is sequentially reflected by the prisms **128** and **130** to be emerged from the prism **130**. When the FLC panel **160** is switch-off, the parallelly polarized blue light Pb is reflected by the FLC panel **160** and maintains its polarization. The reflected parallel polarized blue light Pb' passes through the prisms **128** and **124** and is then reflected by the prism **120** and emerges along the direction of the incident light Ip.

According to the description above, if a fast pulse voltage source is connected to the FLC panels **140**, **150** and **160**, the vertically polarized lights of red color, green color and blue color can be sequentially brought out from the right side of the prism **130**.

According to another embodiment of this invention, the color separator is constructed as shown in FIG. 5, which is similar to the embodiment of FIG. 3. However, the incident light used in this embodiment is a vertically polarized white light Is. The spectrum of the dichroic prism **220** is as shown in FIG. 6A. The spectrum of the dichroic prism **222** is as shown in FIG. 6B. The spectrum of the dichroic prism **224** is as shown in FIG. 6C. The spectrum of the dichroic prism **226** is as shown in FIG. 6D. The spectrum of the dichroic prism **228** is as shown in FIG. 6E. The spectrum of the dichroic prism **230** is as shown in FIG. 6F.

Referring to FIG. 7, the color separator of this invention can be combined with a transmissive liquid crystal display module **170** and a projection lens set **180** to constitute a time-sequential full color liquid crystal projector. Another embodiment is as shown in FIG. 8, in which the color separator is combined with a reflective liquid crystal display module **190** and a projection lens **180** to constitute a time-sequential full color liquid crystal projector.

The CIE coordinates of the light beams of red color, green color and blue color of the full color liquid crystal projector using the color separator of this invention are plotted in FIG. 9. In the drawing, the triangular area indicated by the symbol "○" represents the gamut of the prior-art color switch called "ColorSwitch α", and the triangular area indicated by the symbol "Δ" represents the gamut of the color separator of this invention. It is found that the color separator of this invention can obtain color lights having a better color purity.

Compared with the prior arts, this invention has the following advantages:

(i) the contrast ratio of the color separator is improved since the FLC panels used are reflective liquid crystal panels.

(ii) the color separator has a simpler structure than that using a transmissive liquid crystal panel as shown in FIG. 2.

(iii) the manufacturing process is simple since no precision alignment is required.

(iv) the light can be reflected back along the incident optical path when the FLC panel is switch-off,

therefore it is not necessary to use any absorber to absorb the useless light.

Finally, while the invention has been described by way of example and in terms of the preferred embodiment, it is to be understood that the invention is not limited to the disclosed embodiments. On the contrary, it is intended to cover various modifications and similar arrangements as would be apparent to those skilled in the art. Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

What is claimed is:

1. A fast time-sequential color-separating device including a plurality of modules sequentially connected to each

other, in which each module includes a dichroic mirror, which can pass a certain wavelength range of light having a first polarization and reflect the other wavelength range of light having a first polarization, a polarizing beam-splitter for said certain wavelength range and a liquid crystal panel that can change the polarization of a light reflected by the liquid crystal panel if an external electric field is applied thereto, wherein the light having a first polarization reflected by the liquid crystal panel is reflected along the incident optical path while no external electric field is applied to the liquid crystal, the light having a first polarization reflected by the liquid crystal panel becomes a light having a second polarization if an external electric field is applied thereto, the light having a second polarization is then reflected by the polarizing beam splitter and is emitted along a direction that is orthogonal to the incident light, various modules passing various wavelength ranges are connected one by one, an external electric field is sequentially applied to the liquid crystal panel of each module, so that various wavelength ranges of lights having a first polarization is turned to lights having a second polarization and are sequentially emitted along the direction orthogonal to the incident light.

2. The color-separating device as claimed in claim **1** wherein the liquid crystal panel is a ferroelectric liquid crystal panel.

3. The color-separating device as claimed in claim **1** wherein the various wavelength ranges include the wavelength ranges of red light, green light and blue light.

4. A fast time-sequential color-separating device including:

- a prism module for separating an incident light into various wavelength ranges of light beams which are emitted from various prisms of the prism module;
- a plurality of ferroelectric liquid crystal panels, respectively placed on emerging surfaces of the various wavelength ranges of light beams, to reflect the various wavelength ranges of light beams to the prism module; and
- a power supply, respectively connected to the plurality of ferroelectric liquid crystal panels, for fast-switching the liquid crystal panels, respectively, to sequentially emit the various wavelength ranges of light beams from the prism module.

5. The color-separating device as claimed in claim **4** wherein the prism module includes six dichroic prisms.

6. The color-separating device as claimed in claim **4** wherein the power supply is a continuous pulse source.

7. The color-separating device as claimed in claim **4** wherein the number of the ferroelectric liquid crystal panels is 3.

8. The color-separating device as claimed in claim **4** wherein the various wavelength ranges include the wavelength ranges of red light, green light and blue light.

9. The color-separating device as claimed in claim **5** wherein the dichroic prism is replaced by a dichroic mirror.

10. A fast time-sequential color-separating liquid crystal projector including:

- a prism module that separates an incident light into various wavelength ranges of light beams which are emitted from various prisms of the prism module;
- a plurality of ferroelectric liquid crystal panels, respectively placed on emerging surfaces of the various wavelength ranges of light beams, to reflect the various wavelength ranges of light beams to the prism module; and
- a power supply, respectively connected to the plurality of ferroelectric liquid crystal panels, fast-switching the liquid crystal panels, respectively, to sequentially emit the various wavelength ranges of light beams from the prism module;
- a display module that receives and modulates the various wavelength ranges of light beams sequentially emitted from the prism module and then projects modulated light beams.

11. The liquid crystal projector as claimed in claim **10** wherein the display module is a single panel of transmissive liquid crystal light valve.

12. The liquid crystal projector as claimed in claim **10** wherein the display module is a single panel of reflective liquid crystal light valve.

13. The liquid crystal projector as claimed in claim **10** wherein the various wavelength ranges include the wavelength ranges of red light, green light and blue light.

14. The liquid crystal projector as claimed in claim **10** wherein the prism module includes six dichroic prisms.

15. The liquid crystal projector as claimed in claim **10** wherein the number of the ferroelectric liquid crystal panels is 3.

16. The liquid crystal projector as claimed in claim **10** wherein the power supply is a continuous pulse source.

17. The liquid crystal projector as claimed in claim **11** wherein the liquid crystal light valve is a ferroelectric liquid crystal light valve.

18. The liquid crystal projector as claimed in claim **12** wherein the liquid crystal light valve is a ferroelectric liquid crystal light valve.

* * * * *

EXHIBIT E

US006883932B2

(12) **United States Patent**
Pan et al.

(10) **Patent No.: US 6,883,932 B2**
(45) **Date of Patent: Apr. 26, 2005**

(54) **APPARATUS FOR IMPROVING UNIFORMITY USED IN A BACKLIGHT MODULE**

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(73) Assignee: **Industrial Technology Research Institute**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/668,169**

(22) Filed: **Sep. 24, 2003**

(65) **Prior Publication Data**

US 2005/0013131 A1 Jan. 20, 2005

(30) **Foreign Application Priority Data**

Jul. 17, 2003 (TW) .... 92119538 A

(51) **Int. Cl.**[7] **F21S 4/00**

(52) **U.S. Cl.** **362/225**; 362/27; 362/29; 362/31; 362/558; 362/561

(58) **Field of Search** 362/225, 26, 27, 362/29, 31, 558–561, 240, 241, 246; 349/58, 349/62, 67, 69, 70

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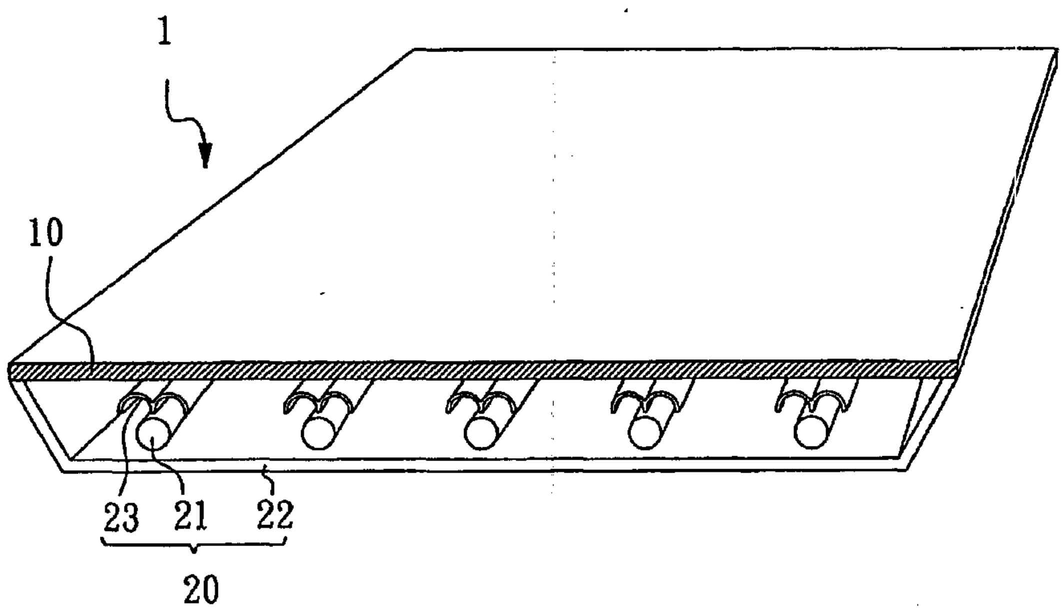
Primary Examiner—Sandra O'Shea
Assistant Examiner—Mark Tsidulko
(74) *Attorney, Agent, or Firm*—Bacon & Thomas

(57) **ABSTRACT**

An apparatus for improving uniformity used in backlight module is disclosed, which includes a plurality of light sources for providing an illuminating light; a reflective housing adjacent to the light sources for receiving the light sources and reflecting the illuminating light; and at least one structured arc sheet locating at the periphery of the light source for making the illuminating light uniform.

10 Claims, 4 Drawing Sheets



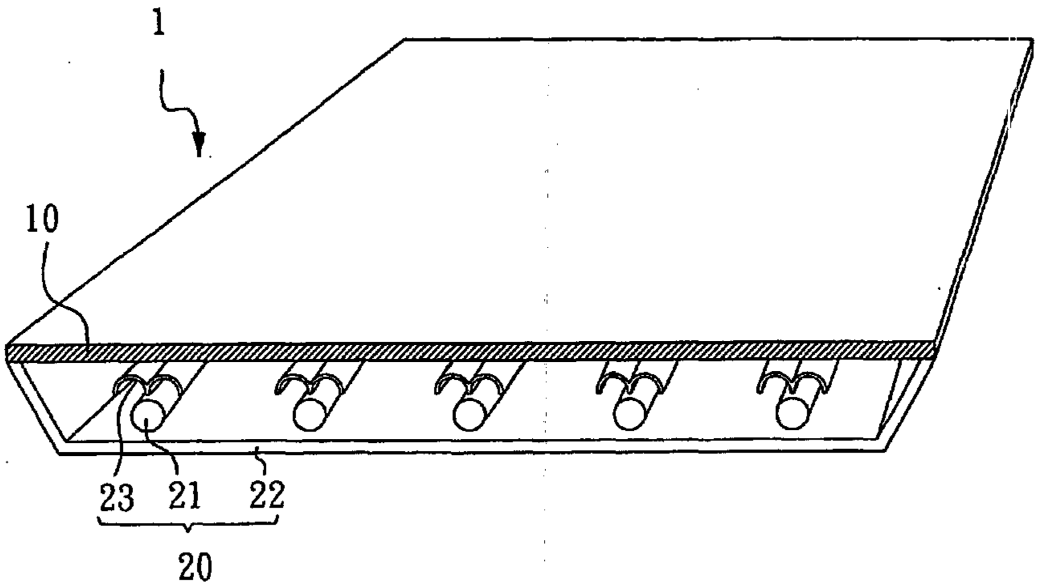


FIG. 1

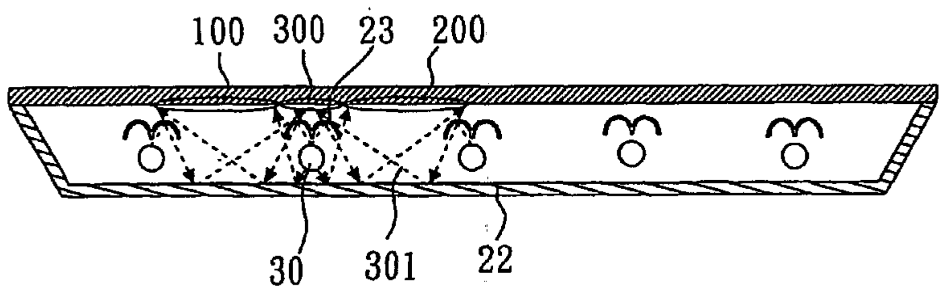


FIG. 2

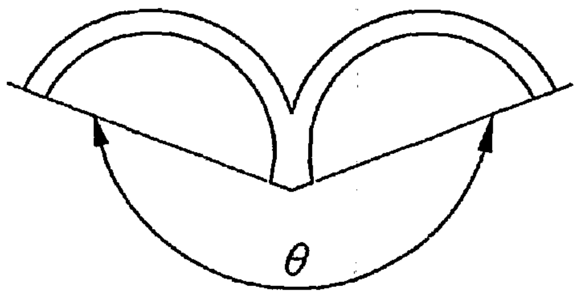


FIG. 3a

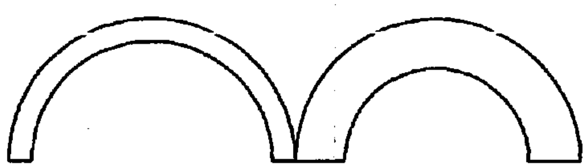


FIG. 3b

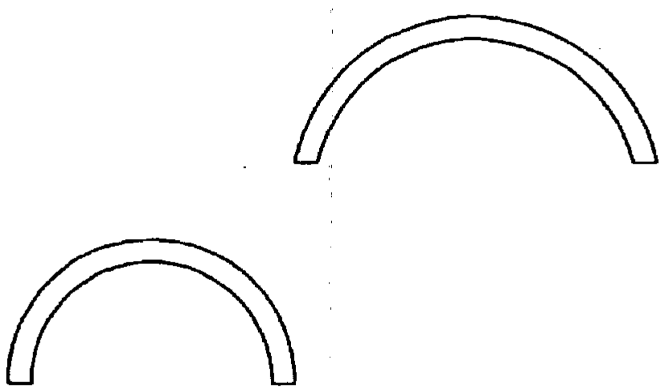
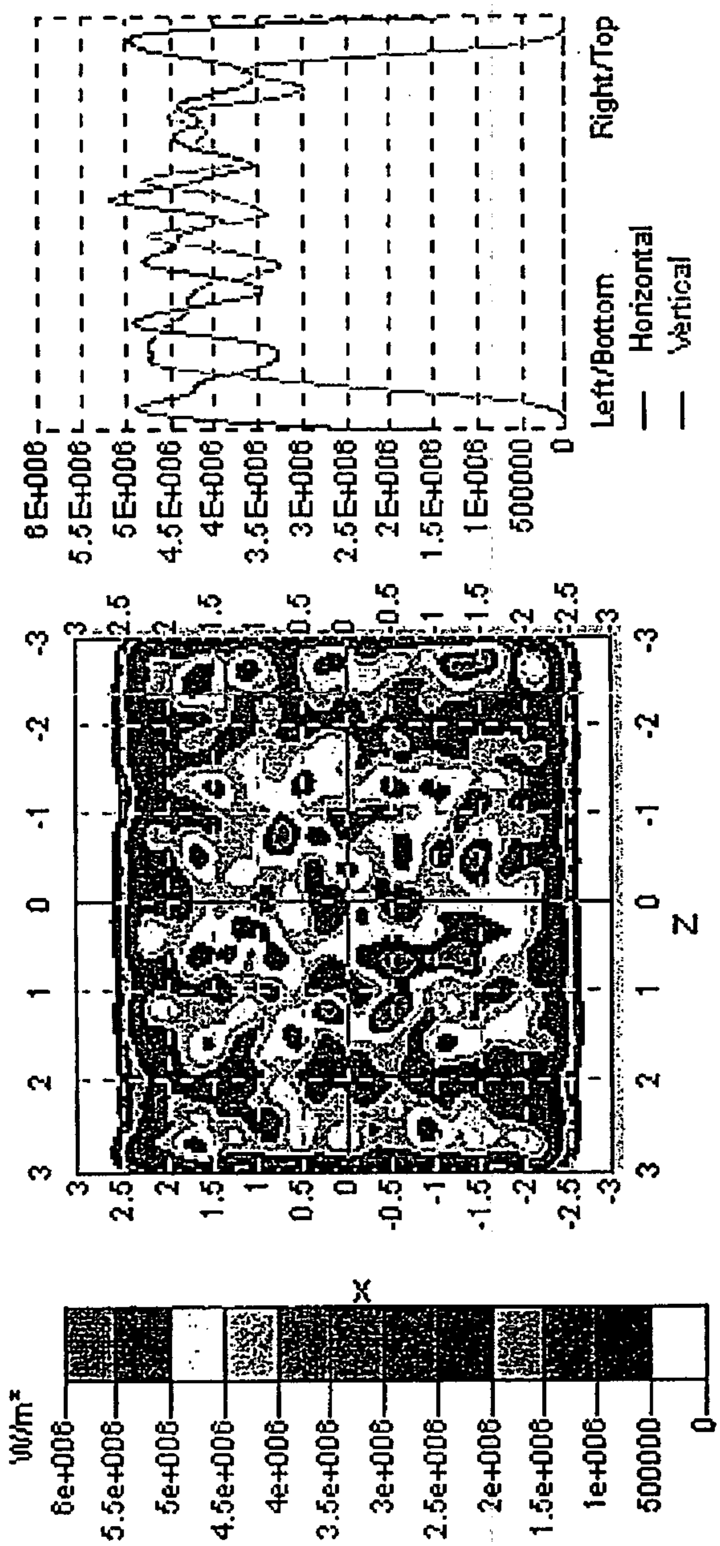


FIG. 3c



Left/Bottom
Right/Top
Horizontal
Vertical
6E+006
5.5E+006
5E+006
4.5E+006
4E+006
3.5E+006
3E+006
2.5E+006
2E+006
1.5E+006
1E+006
500000
0
Z
X
W/m²
6e+006
5.5e+006
5e+006
4.5e+006
4e+006
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1e+006
500000
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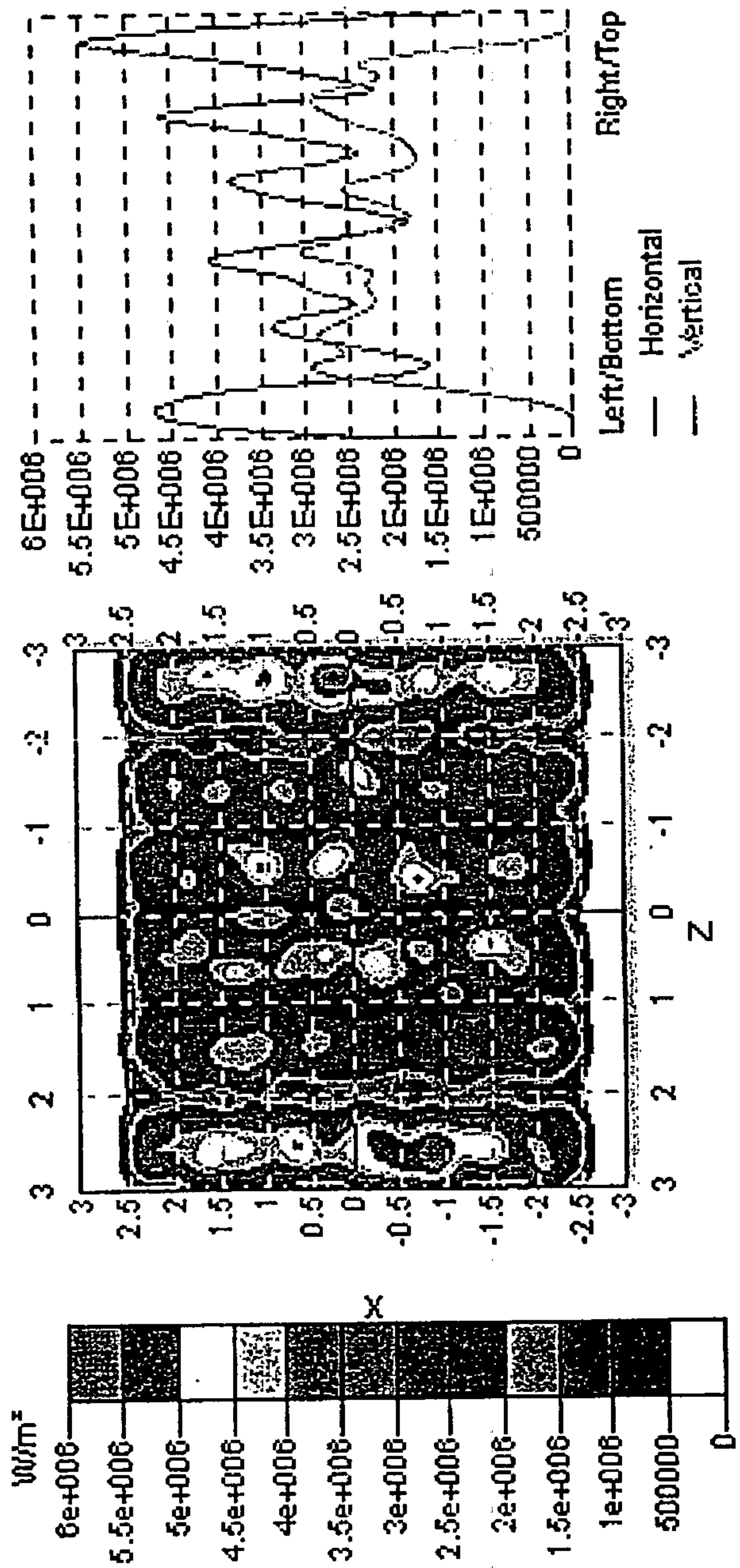
FIG. 4



Right/Top
Left/Bottom
Horizontal
Vertical
6E+006
5.5E+006
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4E+006
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3E+006
2.5E+006
2E+006
1.5E+006
1E+006
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X
W/m²
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1e+006
500000
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FIG. 5

APPARATUS FOR IMPROVING UNIFORMITY USED IN A BACKLIGHT MODULE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an apparatus for improving uniformity used in a backlight module and, more particularly, to an apparatus that provides improved illumination uniformity for a liquid crystal display (LCD) or a liquid crystal TV.

2. Description of Related Art

Currently, there are two types of lighting module for a flat panel display. One is the back type, and the other is the front type. The backlight module is further classified as a side-light (edge-light) type and a directly-under-light (bottom light) type according to their locations of light sources. The directly-under-light backlight module is mostly used in a stationary product, such as a desktop LCD or an LC TV as it has a heavy appearance. Because the light source of a directly-under-light backlight module is located right under the displaying area, the profile of the light sources easily causes a non-uniformity of brightness, shadows, or line defects to the displaying image. Generally, a light-diffusing sheet is used to uniformly diffuse the illuminating light so that the shadows or line defects are blurred. Additionally, some light diffusing sheets are mounted with micro particles having various sizes and densities for refracting or diffusing the illuminating light as uniformly as possible. However, the illuminating light will be absorbed when passing through the light-diffusing sheet and only about 50% of the original is remains, which leads to a low efficiency of light utility rate.

Therefore, it is desirable to provide an improved an apparatus for improving uniformity used in a backlight module to mitigate and/or obviate the aforementioned problems.

SUMMARY OF THE INVENTION

The object of the present invention is to provide an apparatus for improving uniformity used in backlight module so that the shadows or line defects are prevented from appearing, the uniformity and utility rate of illuminating light are increased, and an improved image quality is obtained.

To achieve the object, the apparatus for improving uniformity used in backlight module of the present invention includes a plurality of light sources for providing an illuminating light; a reflective housing adjacent to the light sources for receiving the light sources and reflecting the illuminating light; and at least one structured arc sheet locating at the periphery of the light source for making the illuminating light uniform.

The light source of the apparatus for improving uniformity used in backlight module of the present invention is preferably a light-emitting diode, an electro-luminescent device, or a cold cathode fluorescent lamp. The arrangement of the light sources is not restricted. Preferably, the light sources are parallel and equally spaced to each other. Preferably, the reflective housing of the present invention is made by stamping or by extrusion. More preferably, the surface of the reflective housing is coated with a reflecting and diffusing material. The apparatus for improving uniformity used in the backlight module of the present invention preferably further comprises a light enhancement unit for raising the semi-brightness angle of the illuminating light,

and more preferably the light sources are located between the light enhancement unit and the reflective housing. The structured arc sheet of the present invention is preferably made of total reflection, transparent, or semi-reflection and semi-transparent materials. The curvature diameter of the structured arc sheet is not restricted and is preferably longer than the diameter of the CCFL. The structured arc sheet is preferably made of metal, polymethyl methacrylate (PMMA), polycarbonate (PC), or glass. Preferably, each of the light sources of the present invention has two structured arc sheets at its periphery, and the angle included by the two structured arc sheets ranges from 30 degrees to 270 degrees. The relative position of the two structured arc sheets is not restricted, and could be at the same plane or not. Preferably, the structured arc sheets are at the same plane. The thicknesses of the structured arc sheets could be the same or different, as could be the curvatures of the structured arc sheets. Preferably, the apparatus for improving uniformity used in the backlight module of the present invention is used in a liquid crystal display (LCD).

Other objects, advantages, and novel features of the invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a preferred embodiment of the backlight module of the present invention;

FIG. 2 is a cross-section that illustrates the pathway of the illuminating light of the preferred embodiment of the present invention;

FIGS. *3a~3c* are perspective views of the various combinations of the structured arc sheets of the present invention;

FIG. 4 shows the simulation result of the preferred embodiment of the present invention; and

FIG. 5 shows the simulation result of no structured arc sheet.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to FIG. 1, there is shown a perspective view of a preferred embodiment of the present invention. The liquid crystal display 1 includes a liquid crystal module (LCM) **10** and a backlight module **20**. The liquid crystal module **10** is composed of two substrates and a liquid crystal layer therebetween. The backlight module **20** has a plurality of light sources **21**, a reflective housing **22**, and structured arc sheets **23**. The light sources **21** are parallel cold cathode fluorescent lamps below the liquid crystal module **10** to which the light sources provide the illuminating light. The reflective housing **22** is below the light sources **21** for receiving the light sources **21** and reflecting the illuminating light. The structured arc sheet **23** may be located at any side of the light source **21** and between the liquid crystal module **10** and the reflective housing **22**. In the present example, two reflective structured arc sheets are mounted over each CCFL for alternating the pathway of the illuminating light and making the illuminating light uniform.

With reference to FIG. 2, there is shown a cross-section that illustrates the pathway of the illuminating light of the preferred embodiment of the present invention. The illuminating light **301** from lamp **30** is reflected by the structured arc sheets **23** or the reflective housing **22** firstly, then reflected by the reflective housing **22** or the structured arc

V. INFRINGEMENT OF U.S. PATENT NO. 6,411,357

28. On June 25, 2002, the USPTO issued U.S. Patent No. 6,411,357, entitled "Electrode Structure for a Wide Viewing Angle Liquid Crystal Display" (hereinafter "the '357 patent"). A true and correct copy of the '357 patent is attached hereto as Exhibit C.

29. ITRI is the owner of all right, title, and interest in and to the '357 patent by assignment, with full right to bring suit to enforce the patent, including the right to recover for past infringement damages and the right to recover future royalties, damages, and income.

30. The '357 patent is valid and enforceable.

31. All requirements under 35 U.S.C. § 287 have been satisfied with respect to the '357 patent.

32. Samsung has been and is infringing the '357 patent by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '357 patent, including but not limited to Samsung products bearing flat panel displays such as the Samsung display LN40A630M1F.

33. Samsung has been and is continuing to induce infringement of the '357 patent under 35 U.S.C. § 271(b) and contributes to the infringement of the '357 patent under 35 U.S.C. § 271(c), in conjunction with such acts of making, using, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '357 patent. The infringing instrumentalities have no substantial non-infringing uses.

sheet **23**, respectively, and finally arrives at the regions **100** and **200**. Intuitively, the line defects over the rim of lamp **30** are avoided. However, the illumination of the region **300** over the lamp **30** is reduced. Therefore, the parameters of the structured arc sheets, such as curvature, shape, thickness, location, or material, etc. are adjusted appropriately to meet the requirements. For example, as shown in FIG. 3*a*, the angle θ included by the two structured arc sheets may range from 30 degrees to 270 degrees. The two structured arc sheets are at the same plane, and have the same curvature diameter but different thicknesses, as shown in FIG. 3*b*. Furthermore, the two structured arc sheets may have different curvatures at different planes, as shown in FIG. 3*c*. The light is emitted from the neighboring lamps of lamp **30** and then reflected by the structured arc sheets thereof to make up the insufficient illumination of the region **300** over the lamp **30**. Consequently, a uniform illuminating light is obtained through the optimum design and arrangement of the structured arc sheets.

Afterwards, the TracePro® simulation software is used to carry out a simulation of the dispersion of the illuminating light. FIG. **4** shows the simulation result of the preferred embodiment of the present invention, wherein each CCFL has two structured arc sheets at its periphery. Comparatively, FIG. **5** illustrates the simulation result of no structured arc sheet being used. It can be seen clearly from FIGS. **4** and **5** that the directly-under-light backlight module of the present invention has an enhanced uniformity of illuminating light, no shadows or line defects, and about 70% of utility rate of light so that a vast improvement in image quality is obtained. Furthermore, due to the variety of the adjustable parameters, such as curvature, shape, thickness, location, or material etc. of the structured arc sheets, the displaying performance of the liquid crystal display may be optimized through appropriate regulating of the aforementioned parameters.

Although the present invention has been explained in relation to its preferred embodiment, it is to be understood that many other possible modifications and variations can be made without departing from the spirit and scope of the invention as hereinafter claimed.

What is claimed is:

1. An apparatus for improving uniformity used in a backlight module comprising:

a plurality of light sources for providing an illuminating light;

a reflective housing adjacent to the light sources for receiving the light sources and reflecting the illuminating light; and

two structured arc sheets mounted at the periphery of the light source for making the illuminating light uniform, wherein the angle included by said structured arc sheets ranges from 30 degrees to 270 degrees.

2. The apparatus as claimed in claim **1**, wherein the two structured arc sheets are in the same plane.

3. The apparatus as claimed in claim **1**, wherein the structured arc sheet is made of metal, polymethyl methacrylate (PMMA), polycarbonate (PC), or glass.

4. The apparatus as claimed in claim **1**, wherein the apparatus is used in a liquid crystal display.

5. The apparatus as claimed in claim **1** wherein the two structured arc sheets are not in the same plane.

6. An apparatus for improving uniformity used in a backlight module comprising:

a plurality of light sources for providing an illuminating light;

a reflective housing adjacent to the light sources for receiving the light sources and reflecting the illuminating light; and

two structured arc sheets mounted at the periphery of the light source for making the illuminating light uniform, wherein said structured arc sheets have different thickness or curvature.

7. The apparatus as claimed in claim **6**, wherein the two structured arc sheets are in the same plane.

8. The apparatus as claimed in claim **6**, wherein the structured arc sheet is made of metal, polymethyl methacrylate (PMMA), polycarbonate (PC), or glass.

9. The apparatus as claimed in claim **6**, wherein the apparatus is used in a liquid crystal display.

10. The apparatus as claimed in claim **6** wherein the two structured arc sheets are not in the same plane.

* * * * *

EXHIBIT F

US007125141B2

(12) **United States Patent**
Pao et al.

(10) **Patent No.:** **US 7,125,141 B2**
(45) **Date of Patent:** **Oct. 24, 2006**

(54) **APPARATUS FOR HOMOGENEOUSLY DISTRIBUTING LIGHTS**

(75) Inventors: **Yu-Nan Pao**, Hsinchu (TW); **Yu-Cheng Lin**, Hsinchu (TW); **Tsung-Hsin Lin**, Hsinchu (TW); **Kuen-Lung Lin**, Hsinchu (TW)

(73) Assignee: **Industrial Technology Research Institute**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/782,845**

(22) Filed: **Feb. 23, 2004**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Dec. 12, 2003 (TW) .... 92135133 A

(51) **Int. Cl.**
F21V 5/00 (2006.01)

(52) **U.S. Cl.** **362/225**; 362/330; 362/329; 362/339; 362/224

(58) **Field of Classification Search** 362/235, 362/249, 327, 328, 329, 330, 331, 332, 339, 362/225, 217, 223, 224, 29, 237, 240, 244
See application file for complete search history.

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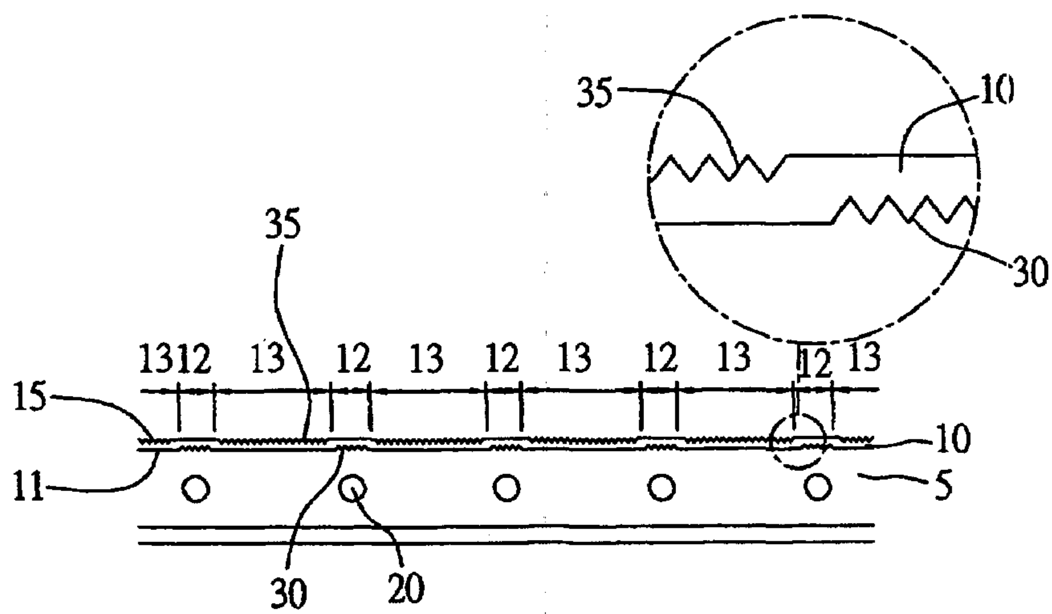
Primary Examiner—Thomas M. Sember
(74) *Attorney, Agent, or Firm*—Rabin & Berdo, P.C.

(57) **ABSTRACT**

An apparatus for homogeneously distributing lights includes a light guide plate, an incidence microstructure and an emergence microstructure. The incidence microstructure is arranged on a surface of the light guide plate and opposite to a light source. The emergence microstructure is arranged on a surface of the light guide plate opposite to the incidence microstructure. The lights emitted by the light source pass through said apparatus thereby being homogenously distributed. Thus the manufacture costs are lowered, and the light source utilization ratio is increased.

11 Claims, 6 Drawing Sheets



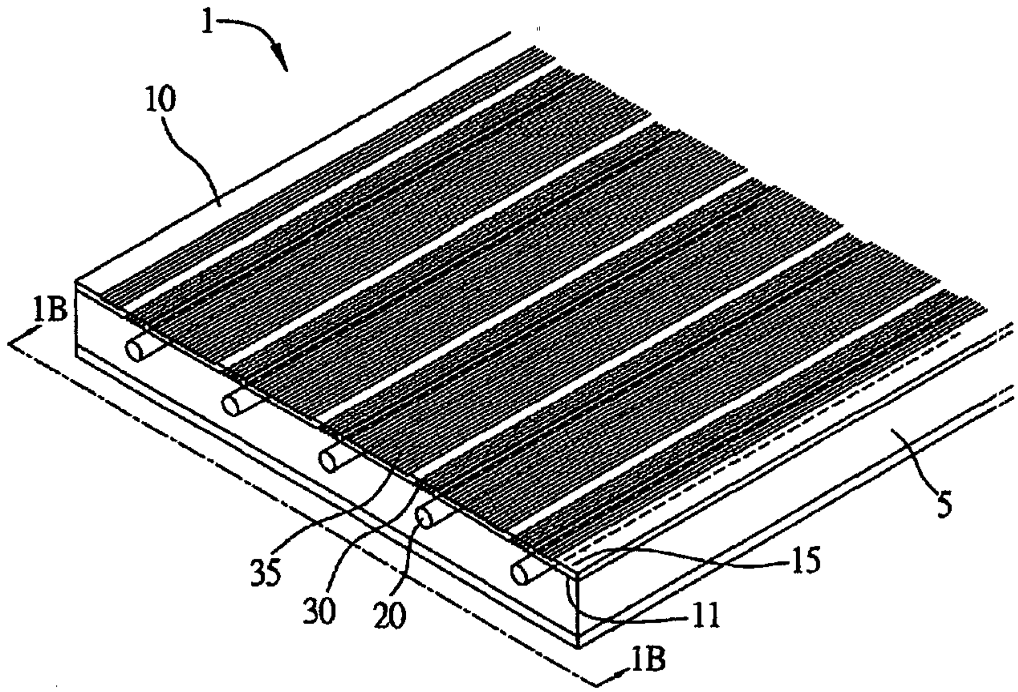

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FIG. 1A

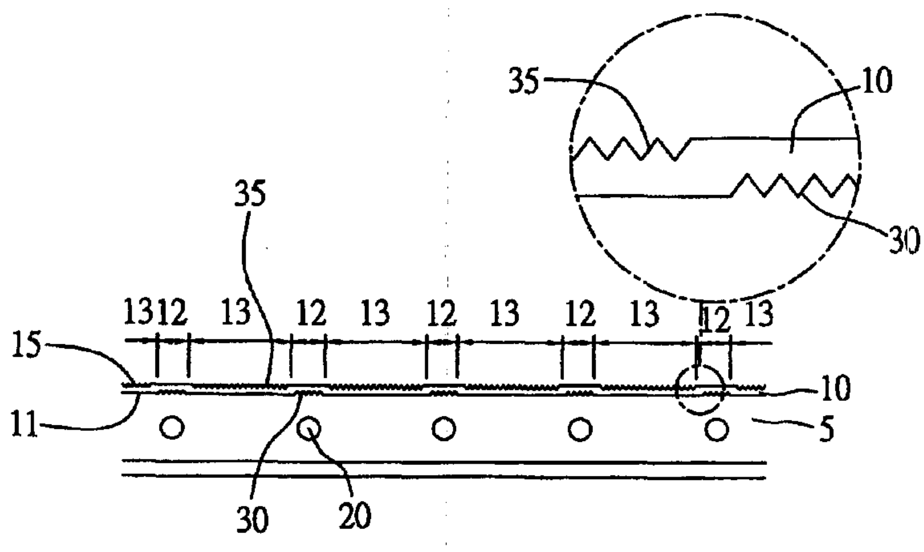
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FIG. 1B

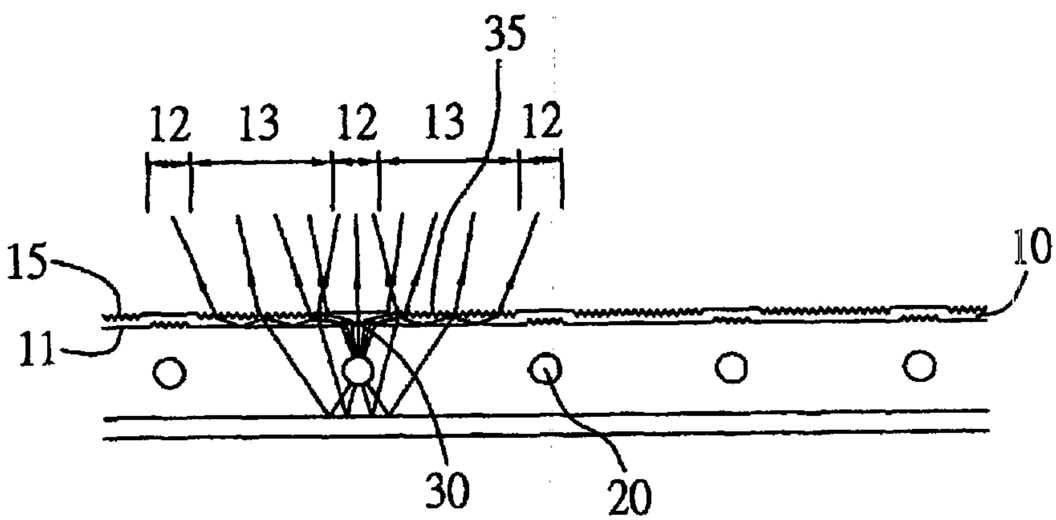

FIG. 2

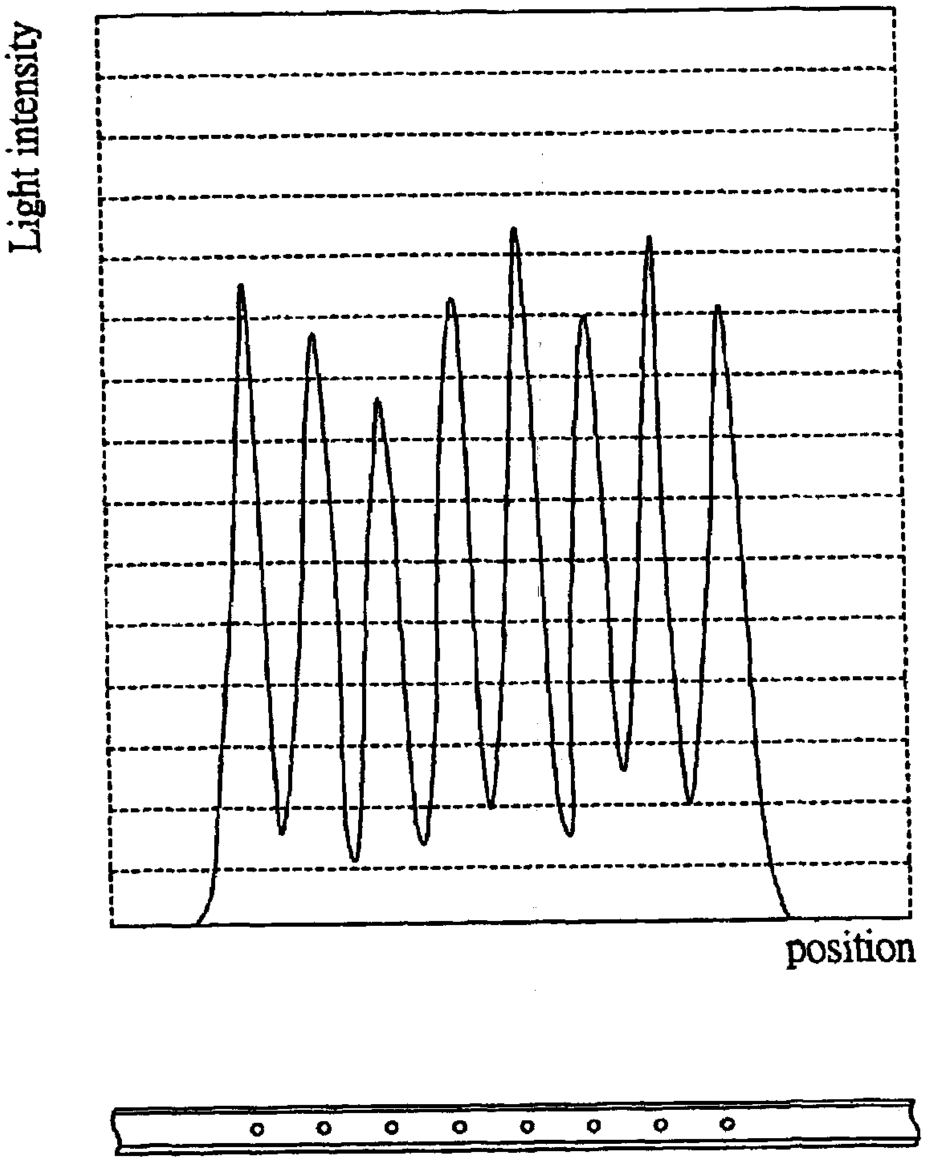

FIG. 3A PRIOR ART

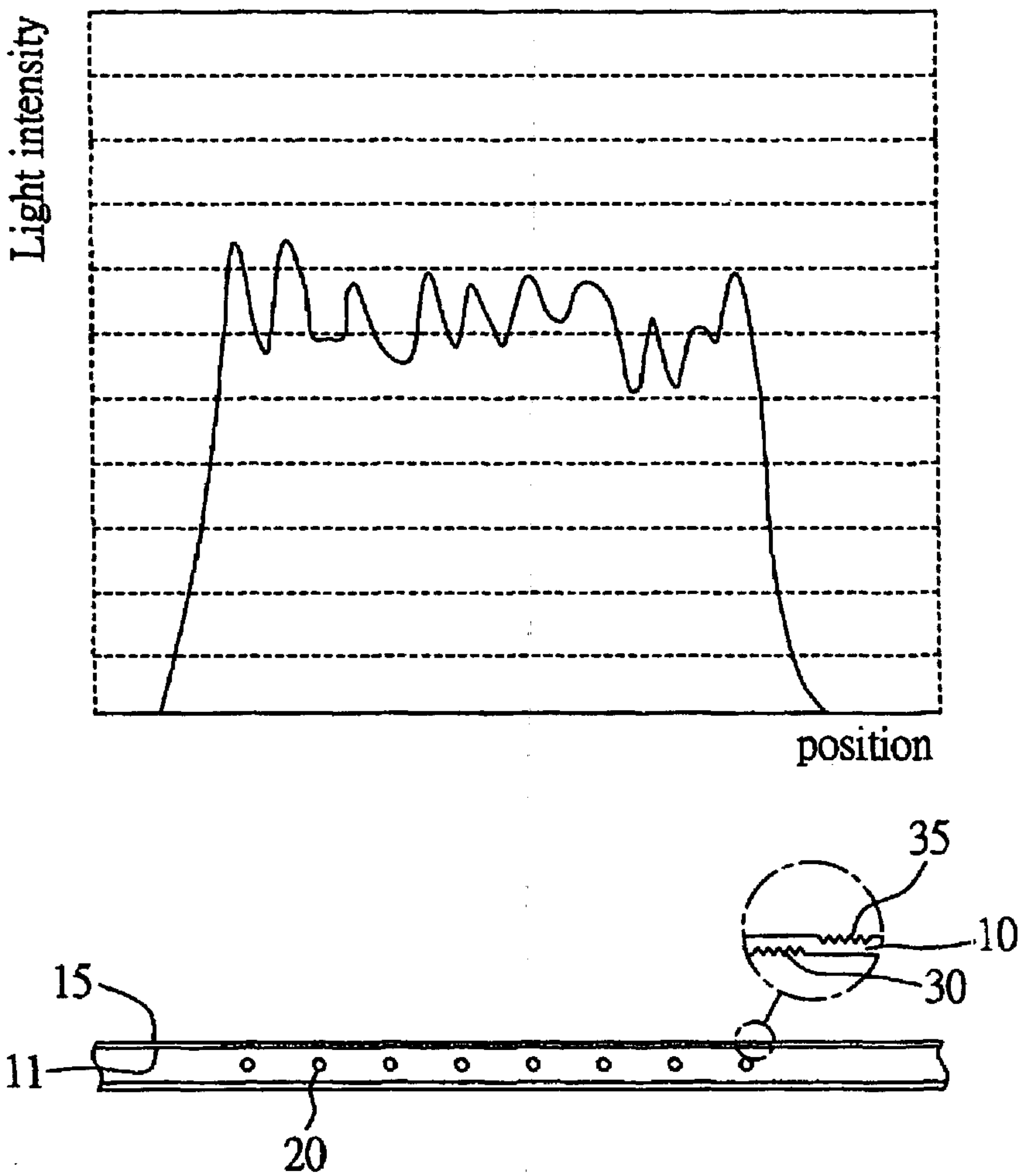

FIG. 3B

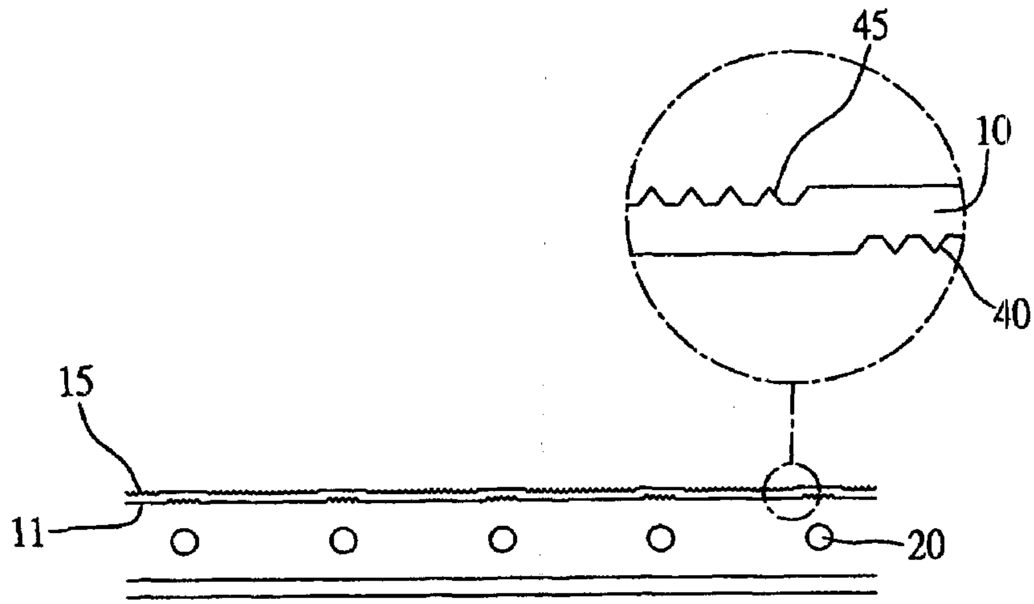

FIG. 4

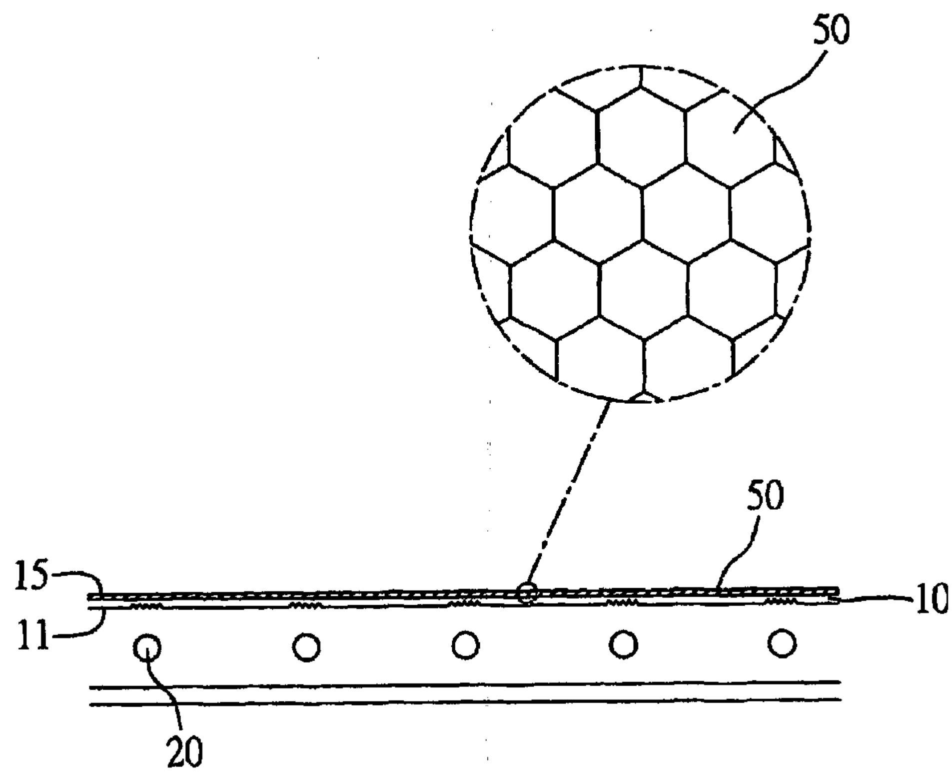

FIG. 5

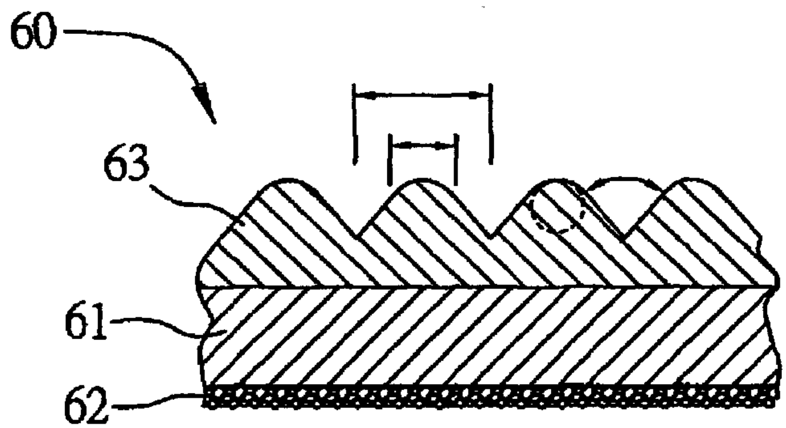

FIG. 6 (PRIOR ART)

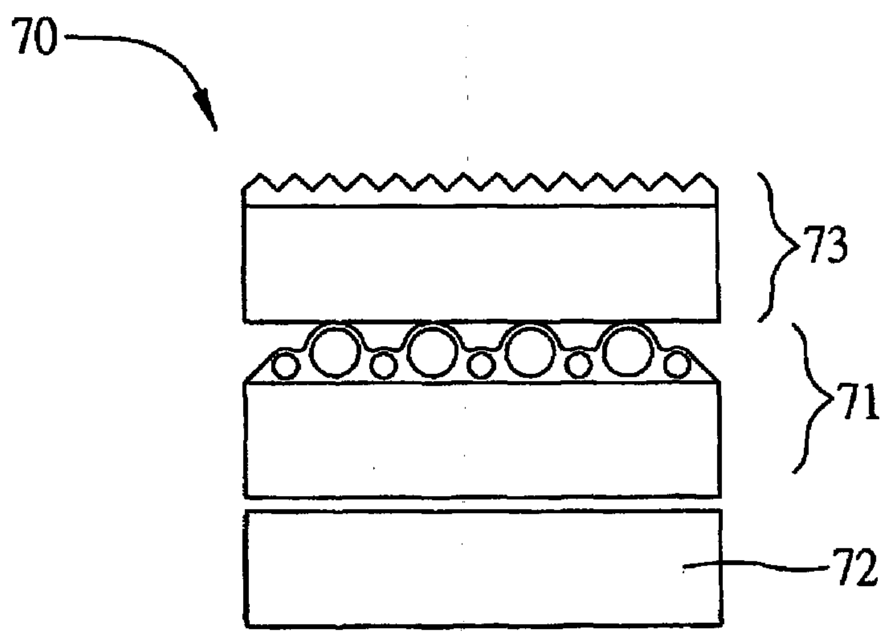

FIG. 7 (PRIOR ART)

APPARATUS FOR HOMOGENEOUSLY DISTRIBUTING LIGHTS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to an apparatus for homogeneously distributing lights, and more particularly, to an apparatus for homogeneously distributing lights applied to a direct type backlight module.

2. Description of the Related Art

Large-scale liquid crystal display (LCD) is mainly applied to a notebook computer or an LCD monitor. Liquid crystal material does not emit light itself. Therefore an external light source is needed for displaying images. Because of a trend of light, thin, short and small styles of a light source of a backlight module, and a requirement for being applied to a large-scale panel, such as an LCD television (TV), the backlight module is not only supposed to have the above-mentioned advantages, but also have other advantages, such as high display luminance, broad visual angle, distinct image contrast and long life. Therefore, direct type backlight module, which is designed for solving the limitations of low luminance in lateral sides thereof and unhomogeneously distribution of the lights, when used in large-scale panels, takes full advantage of its high display luminance to apply direct type linear light source for homogeneously distributing the lights; converts the homogeneous lights into area lights; and imports the area lights to the illumination area.

General light source of direct type backlight module is cold cathode fluorescernt lamp (CCFL) or light emitting diode (LED). The CCFL has properties like high brightness, high efficiency and long life, and has a cylinder-shaped configuration which is easily coupled with light reflection components to form laminal lighting device. Therefore the CCFL has become the mainstream light emergence component. However, CCFLs are often arranged in a row and disposed at a bottom of an LCD panel, thereby the images displayed on the LCD are asymmetric in light intensity distribution because the diffusion angles of the scattered lights are usually too large, and the light emergence directions are usually disordered. Thus obvious profiles of the CCFLs are shown on the screen, which damage the quality of the images. Therefore, under the circumstance of direct type backlight module being applied, the larger of the dimension of the LCD panel and the greater of the number of the CCFLs are used, the more serious of the deficiency of black and white stripes shown on the screen occurs. The above mentioned problem is a main bottle-neck in the way of the development of the LCD display quality.

To solve the above mentioned problem, diffusion components and prisms are disposed between the CCFLs and the LCD panel to diffuse and then converge the lights. Therefore the lights emitted by the CCFLs are diffused, and then the diffusion angle is reduced for being efficiently coupled with the LCD panel, thereby homogeneously distributing the lights. However, the above design applies so many optical components as to not easy to be manufactured, and sharply increase the costs. Furthermore, the effect of homogeneously distributing the lights of the design is finite, and not the best solution to solve the problem.

Referring to FIG. 6, U.S. Pat. No. 6,280,063 discloses a multi-layer brightness enhancement article **60** for enhancing the on-axis luminance of a diffuse lighting device. The brightness enhancement article **60** comprises a base layer **61**, a separate layer **62** plated on the a bottom of the base layer **61**, and a microstructure layer **63** arranged on a side of the

base layer **61** opposite to the separate layer **62**. The separate layer **62** is used for diffusing the lights. The microstructure layer **63** is used for converging the diffused lights. By using the separate layer **62** and the microstructure layer **63**, the lights are homogeneously distributing. However, different processes are required in this invention for respectively forming the separate layer **62** and the microstructure layer **63**, thereby increasing the manufacture costs. Furthermore, the processes are complicated and not suitable for mass production, and the effect of homogeneously distributing the lights can not satisfy the images quality requirements of consumers.

Referring to FIG. 7, US Pub. No. 20020001055 discloses a backlight module structure **70**, which applies resin particles to form a light diffusion layer **71**. The light diffusion layer **71** diffuses the lights emitted by a backlight source **72** with wide-angle. A prism sheet **73** then converges the lights to achieve an effect of homogeneous diffusion. However, the backlight module structure **70** comprises so many components that leads to a complicated manufacture process and increases the manufacture costs. Furthermore, the homogeneous diffusion effect and the efficiency of the light utilization can not satisfy the market demands.

Additionally, conventional method also increases the number and the arrangement density of the CCFLs to solve the problems of unhomogeneously distributing the lights and of the profiles of the CCFLs being shown on the screen. However, the method greatly increases the manufacture costs. Furthermore, because of the configure limitation, if any one of the CCFLs failures, the whole row of CCFLs will be replaced with a new one. Under the circumstance of the number of the CCFLs being increased, the chance and frequency of CCFL failure and replace are correspondingly increased. Thus the service life of the whole LCD panel is shortened.

Thus an improved apparatus applied in the direct type backlight module for homogeneously distributing the lights, efficiently utilizing the light source, greatly lowering the manufacture costs and meeting the demands of the market is desired.

SUMMARY OF THE INVENTION

The primary objective of the present invention is to provide an apparatus for homogeneously distributing lights, which efficiently controls the light emergence direction and homogeneously distributing the lights.

Another objective of the present invention is to provide an apparatus for homogeneously distributing lights, which improves the light source utilization ratio.

A further objective of the present invention is to provide an apparatus for homogeneously distributing lights, which applies fewer optical films, and cuts down the manufacture costs.

And yet another objective of the present invention is to provide an apparatus for homogeneously distributing lights, which is suitable for mass production.

In accordance with the above and other objectives, the present invention proposes an apparatus for homogeneously distributing lights. The apparatus includes a light guide plate, an incidence microstructure and an emergence microstructure. The incidence microstructure is arranged on a surface of the light guide plate and opposite to a light source. The emergence microstructure is arranged on a surface of the light guide plate opposite to the incidence microstructure. The lights emitted by the light source pass through said apparatus thereby being homogenously distributed.

34. Samsung had and continues to have actual knowledge of the '357 patent and their coverage of Samsung's infringing instrumentalities, but has nonetheless engaged in the infringing conduct. Samsung's infringement of the '357 patent was and continues to be willful.

35. As a direct and proximate result of Samsung's acts of patent infringement, ITRI has been and continues to be injured and has sustained and will continue to sustain substantial damages.

36. Unless Samsung is enjoined by this Court from continuing their infringement of the '357 patent, ITRI will suffer additional irreparable harm and impairment of the value of its patent rights.

37. ITRI has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and ITRI is entitled to recover its reasonable and necessary attorneys' fees, costs, and expenses.

VI. INFRINGEMENT OF U.S. PATENT NO. 6,768,526

38. On July 27, 2004, the USPTO issued U.S. Patent No. 6,768,526, entitled "Time-Sequential Color Separator and Liquid Crystal Projector Using the Same" (hereinafter "the '526 patent"). A true and correct copy of the '526 patent is attached hereto as Exhibit D.

39. ITRI is the owner of all right, title, and interest in and to the '526 patent by assignment, with full right to bring suit to enforce the patent, including the right to recover for past infringement damages and the right to recover future royalties, damages, and income.

The apparatus can be applied to a backlight module of a liquid crystal display (LCD) panel. The incidence microstructure and emergence microstructure are manufactured by ultra-precision machining or micro-electro-mechanical system (MEMS). The incidence microstructure or emergence microstructure is one of the continuous and discontinuous honeycombed, circular, irregular or circular dot structure, or of a micro lens array structure, or any one of said structure incorporating a plurality of micro particles. The guide light plate having a refractive index greater than the outside environment is made of a light transmitting polymer material and semi light transmitting polymer material. The light source is a plurality of parallel cold cathode fluorescernt lamps (CCFLs).

The emergence microstructure of the emergence surface is designed for damaging total reflection of the lights in the light guide plate, thereby the lights experienced at least one time total reflection pass through the emergence surface where does not correspond to the light source, and emit to the outside environment environment. Thus the directions of the lights passing through the incidence microstructure of the incidence surface are changed, accordingly, the lights are homogeneously distributed, and further the light source utilization ratio is increased.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings included herein provide a further understanding of the invention. A brief description of the drawings is as follows:

FIGS. 1A and 1B are schematic views of an apparatus for homogeneously distributing lights applied in a backlight module in accordance with a preferred embodiment of the present invention;

FIG. 2 is a schematic view of light passages of the apparatus of FIGS. 1A and 1B;

FIG. 3A is a light intensity distribution chart of a conventional backlight module;

FIG. 3B is a light intensity distribution chart of the backlight module applying the apparatus of FIG. 1A and/or FIG. 1B;

FIG. 4 is an alternative embodiment of the apparatus for homogeneously distributing lights of the present invention;

FIG. 5 is still an alternative embodiment of the apparatus for homogeneously distributing lights of the present invention;

FIG. 6 is a schematic view of a conventional multi-layer brightness enhancement article disclosed in U.S. Pat. No. 6,280,063; and

FIG. 7 is a schematic view of a conventional backlight module structure disclosed in US Pub. No. 20020001055.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Embodiments of an apparatus for homogeneously distributing lights 1 (this is referred to simply as "apparatus") of the present invention will now be explained in detail with reference to the drawings.

Referring to FIGS. 1A and 1B, schematic views of the apparatus 1 applied in a backlight module in accordance with a preferred embodiment of the present invention are shown, wherein the FIG. 1B is a side view of the FIG. 1A. The apparatus 1 is disposed on a surface of a main body of a backlight module 5. The backlight module 5 comprises a plurality of parallel cold cathode fluorescernt lamps (CCFLs) 20. The apparatus 1 comprises a light guide plate

10. The light guide plate 10 comprises an incidence surface 11 and an emergence surface 15. The incidence surface 11 is arranged opposite to the CCFLs 20. Lights emitted by the CCFLs 20 subsequently pass through the incidence surface 11, the main body of the light guide plate 10 and the emergence surface 15, and then emit to an adjacent liquid crystal display (LCD) panel (not shown) for displaying images.

The incidence surface 11 and the emergence surface 15 respectively define a plurality of interlaced first areas 12 and second areas 13. The first areas 12 of the incidence surface 11 and the emergence surface 15 correspond to the CCFLs 20. The second areas 13 of the incidence surface 11 and the emergence surface 15 correspond to the spaces sandwiched between the CCFLs 20. Each first area 12 defines an incidence microstructure 30. Each second area 13 defines an emergence microstructure 35. When the lights emitted by the CCFLs 20 pass through the incidence microstructure 30 and enter the light guide plate 10, the lights are scattered with wide-angle, thereby occurring total reflection in the light guide plate 10. After at least one time total reflection in the light guide plate 10, the lights emit to the outside environment through the emergence microstructures 35. That is, by applying the incidence microstructures 30 and the emergence microstructures 35, the lights emitted by the CCFLs 20 are not only emitted through the first areas 12 of the emergence surface 15, but also through the second areas 13 of the emergence surface 15 to the outside environment. Thus the lights generates by the CCFLs 20 are homogeneously distributed.

More specifically, the light guide plate 10 is made of transparent polymer material having a low light absorbency, or of light transmitting polymer material, or alternately of semi light transmitting polymer material. Said materials have a refractive index greater than that of the outside environment (such as the air) where the CCFLs 20 are located, thereby increasing the chance for occurring total reflection inside the light guide plate 10. The thickness of the light guide plate 10 (i.e. the distance from the incidence surface 11 to the emergence surface 15) can be adjusted according to the requirement and design. In a backlight module, the thickness of the light guide plate 10 is usually in a millimeter (mm) scale. The incidence microstructures 30 and the emergence microstructures 35 are manufactured by ultra-precision machining or micro-electro-mechanical system (MEMS). In the present embodiment, the section view of the incidence microstructure 30 or the emergence microstructure 35 is a longitudinally arranged continuous zigzag structure having a triangle section along the CCFLs 20. The configuration of the incidence microstructure 30 or the emergence microstructure 35 can be designed as a circular structure, a circular dot structure, or an irregular structure; or the angle, height, arrangement density or the like thereof can be various according to different specifications or requirements; or a plurality of micro particles can be mixed therein. Therefore, the passages of the lights are changed for improving the total reflection condition of the light guide plate 10. Chance for occurring total reflection is increased because the incidence angles of the lights entering into the light guide plate 10 through the incidence microstructure 30 are more likely greater than the corresponding critical angle. Consequently, by properly choosing the material and the refractive index of the light guide plate 10, and the location and configuration of the incidence microstructures 30, the probability for the incidence lights occurring total reflection is greatly increased. Furthermore, by properly choosing the location and configuration of the emer-

gence microstructures 35, the probability for the lights entering into outside environment through the second areas 13 of the emergence surface 15 is greatly increased.

Referring to FIG. 2, passages of the lights emitted by the CCFLs 20 are further illustrated (illustrated with the lights emitted from only one CCFL). The lights pass through the incidence microstructure 30 of the first area 12 of the incidence surface 11, and enter into the light guide plate 10. Part of the lights occur total reflection in the light guide plate 10, and transmit along the light guide plate 10. Said lights occurring total reflection then pass through the emergence microstructure 35 which breaches the total reflection condition of the light guide plate 10, and then emitted to the outside environment through the second area 13 of the emergence surface 15. Therefore, the lights emitted from the first area 12 of the emergence surface 15 are greatly decreased, and the lights emitted from the second area 13 of the emergence surface 15 are correspondingly greatly increased. Thus the lights emitted from the whole light guide plate 10 are homogeneously distributed, the deficiency of profiles of the CCFLs 20 shown on the LCD screen of prior arts is eliminated.

Referring to FIG. 3A, a light intensity distribution chart of the CCFLs of conventional backlight module is illustrated. As can be seen, the light intensity is unhomogeneously distributed. Referring to FIG. 3B, a light intensity distribution chart of the CCFLs of present invention is illustrated. As can be seen, compared with FIG. 3A, the light intensity is substantially homogeneously distributed. By applying the incidence microstructures 30 and the emergence microstructures 35 to the light guide plate 10, the light energy density emitted through the first areas 12 of the emergence surface 15 is greatly decreased, and correspondingly, the light energy density emitted through the second areas 13 of the emergence surface 15 is greatly increased, thereby forming the light intensity distribution shown in FIG. 3B. The apparatus 1 of the present invention is thus homogeneously distributing the lights, simultaneously, the light source utilization ratio is increased, the manufacture processes are simplified, and the manufacture costs are lowered.

The foregoing detail description is only a preferred embodiment of the present invention, in which, the incidence microstructures 30 and emergence microstructures 35 are designed as a continuous shape. However, other structures which can achieve an effect of light diffusion or light total reflection also can be applied to the present invention, the best dimension and designed configuration of the structure can be various in accordance with the specification of the backlight module and the LCD panel, or of the distance from the plurality of CCFLs 20 to the light guide plate 10. Additionally, the feature of the present invention is that the first areas 12 of the incidence surface 11 of the light guide 10 define the incidence microstructures 30 for occurring total reflection, whether or not the emergence microstructures 35 are defined in the emergence surface 15 does not enormously influence the effect of lights homogeneously distributed. Besides the embodiments disclosed above, other embodiments, such as the emergence surface 15 defines the emergence microstructures 35 in all the areas thereof, or the emergence surface 15 does not define the emergence microstructures 35 therein, can also be applied in the present invention.

Referring to FIG. 4, an alternate embodiment of an incidence microstructure 40 (corresponding to the incidence microstructure 30) and an emergence microstructure 45 (corresponding to the emergence microstructure 35) of the present invention is illustrated. The incidence microstructure 40 and emergence microstructure 45 are designed as discontinuous microstructures, and defined in the first areas 12 of the incidence surface 11 and the second areas 13 of the emergence surface 15 by MEMS. The incidence microstructure 40 or emergence microstructure 45 comprises a plurality of evenly spaced teeth for changing the critical angle of total reflection of the lights entering the light guide plate 10, and further for homogeneously distributing the lights. FIG. 5 illustrates another alternate embodiment of an emergence microstructure 50 of the present invention. The emergence microstructure 50 is an uninterrupted micro lens array which is arranged on the emergence surface 15 for changing the condition of total reflection of the lights entering the light guide plate 10, and further for homogeneously distributing the lights. The emergence microstructure 50 can be shaped as one of the honeycombed structure, circular dot structure and irregular structure, or any one of said structure incorporating micro particles.

The above embodiments of the apparatus 1 are described as being applied to a direct type backlight module, whereas the apparatus 1 can also be applied to other device whose lights emitted from a light source need to be guided or distributed to other structures. Furthermore, the light source of the present invention is not limited as the CCFLs 20, but can be any type of light source whose lights directions can be controlled by various incidence microstructures or emergence microstructures.

Conclusively, the apparatus 1 of the present invention can homogeneously distribute lights, improve light source utilization ratio; reduce the usage of optical films, lower the manufacture costs and be applied to mass production.

It should be apparent to those skilled in the art that the above description is only illustrative of specific embodiments and examples of the invention. The invention should therefore cover various modifications and variations made to the herein-described structure and operations of the invention, provided they fall within the scope of the invention as defined in the following appended claims.

What is claimed is:

1. An apparatus for homogeneously distributing lights, comprising

a single-layered light guide plate comprising an incidence surface and an emergence surface each of which defines a plurality of interlaced first areas and second areas, wherein each of the first areas is smaller than any of the second areas;

an incidence microstructure being arranged on the first areas of the incidence surface of the light guide plate and directly in front of and opposite to a light source; and

an emergence microstructure, the emergence microstructure being arranged on the second areas of the emergence surface of the light guide plate opposite to the incidence microstructure;

wherein light emitted by the light source passes through said apparatus thereby being homogeneously distributed.

2. The apparatus as claimed in claim 1, wherein the incidence microstructure is a continuous structure or a discontinuous structure having a triangle cross-section and longitudinally arranged along the light source.

3. The apparatus as claimed in claim 1, wherein the emergence microstructure is a continuous structure or a discontinuous structure having a triangle cross-section and longitudinally arranged along the light source.

4. The apparatus as claimed in claim 1, wherein the emergence microstructure is a micro lens array structure.

5. The apparatus as claimed in claim 4, wherein the micro lens array structure is a structure selected from the groups consisting of honeycombed structure, circular dot structure and irregular structure.

6. The apparatus as claimed in claim 1, wherein the light source is a plurality of lamp.

7. The apparatus as claimed in claim 1, wherein the light guide plate is made of one of a light transmitting polymer material and a semi light transmitting polymer material.

8. The apparatus as claimed in claim 1, wherein the apparatus is applied to a backlight module of an LCD panel.

9. The apparatus as claimed in claim 1, wherein the incidence microstructure is comprised of a plurality of straight grooves.

10. The apparatus as claimed in claim 9, wherein the emergence microstructure is comprised of a plurality of straight grooves.

11. The apparatus as claimed in claim 1, wherein the emergence microstructure is comprised of a plurality of straight grooves.

* * * * *

EXHIBIT G

US007217010B2

(12) **United States Patent**
Lin et al.

(10) **Patent No.: US 7,217,010 B2**
(45) **Date of Patent: May 15, 2007**

(54) **REFLECTOR WITH NEGATIVE FOCAL LENGTH**

(75) Inventors: **Jian-Shian Lin**, Yilan (TW); **Hsiu-Chen Hsu**, Tainan (TW); **Min-Lung Hsieh**, Hsinchu (TW)

(73) Assignee: **Industrial Technology Research Institute**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 56 days.

(21) Appl. No.: **11/088,792**

(22) Filed: **Mar. 25, 2005**

(65) **Prior Publication Data**

US 2006/0139933 A1 Jun. 29, 2006

(30) **Foreign Application Priority Data**

Dec. 29, 2004 (TW) .... 93221148 U

(51) **Int. Cl.**
F21V 7/00 (2006.01)

(52) **U.S. Cl.** **362/300**; 362/297; 362/305; 362/346; 362/347

(58) **Field of Classification Search** 362/297, 362/300, 305, 346, 347
See application file for complete search history.

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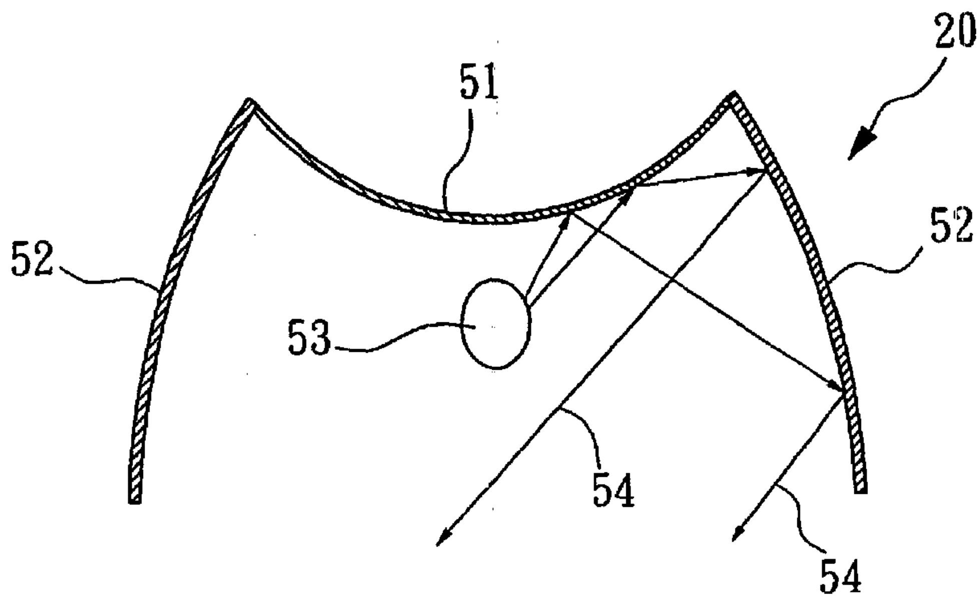
(57) **ABSTRACT**

A luminaire with reflector of negative focal length is disclosed, which comprises a light source and a luminaire screen having a reflector of negative focal length, a side screen and a plate; wherein the reflector of negative focal length is capable of reflecting the upward-incident rays emitted from the light source; and the side screen is capable of reflecting the sideward-incident rays emitted from the light source and the reflected rays of the reflector; and the plate being disposed at the lower portion of the luminaire screen beneath the light source has a plurality of microstructures arranged thereon and is capable of accepting the rays of the downward incident area along with both the reflected rays of the reflector and the side screen so as to diffuse the same for discharging. By the luminaire screen of the invention, the rays emitting from the light source of the luminaire are reflected and directed to a preferred discharging area so as to enable the rays to be discharged out of the luminaire by large angles for reducing glare.

16 Claims, 7 Drawing Sheets



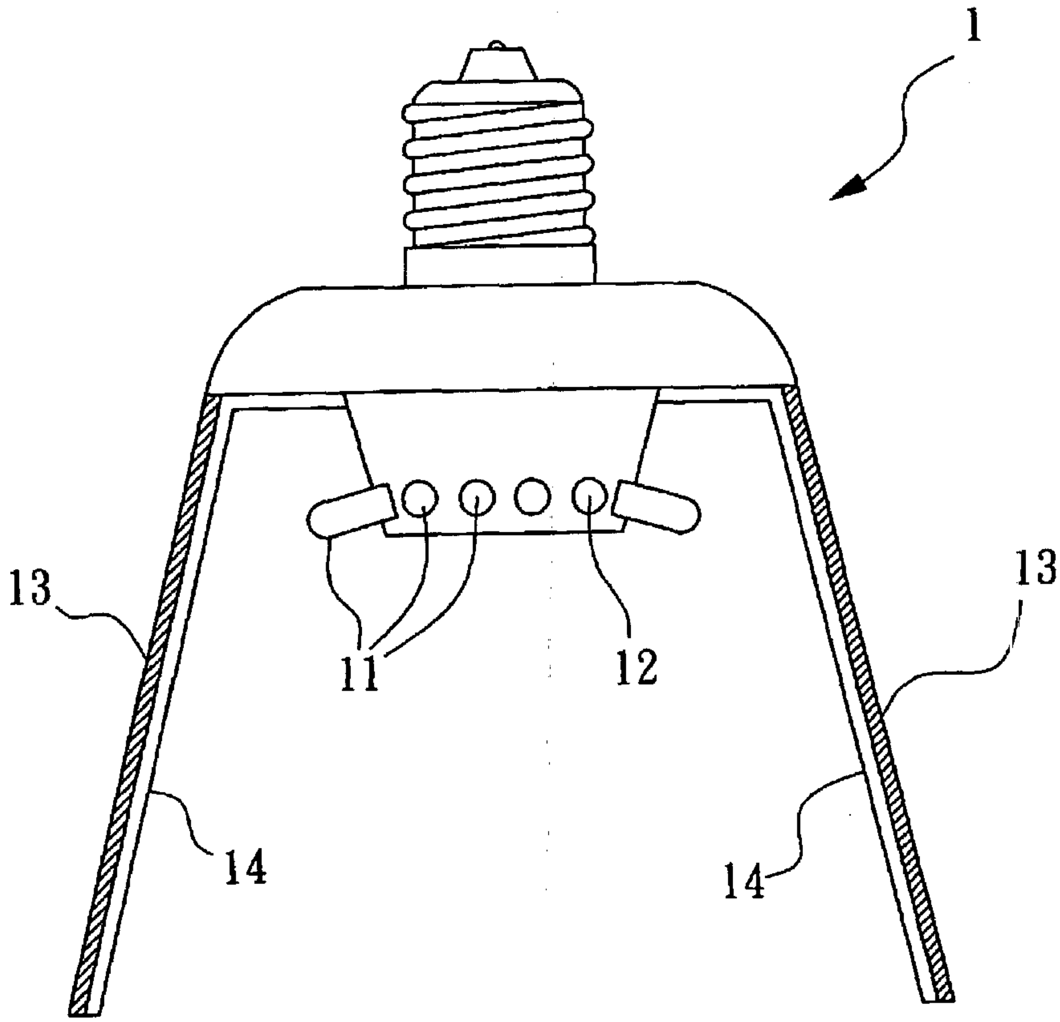


FIG. 1
(PRIOR ART)

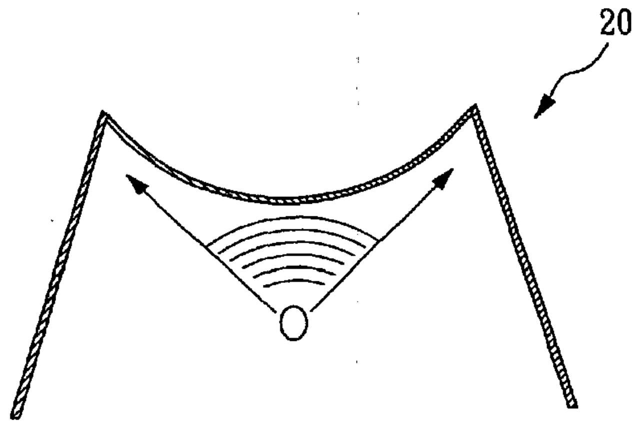


FIG. 2

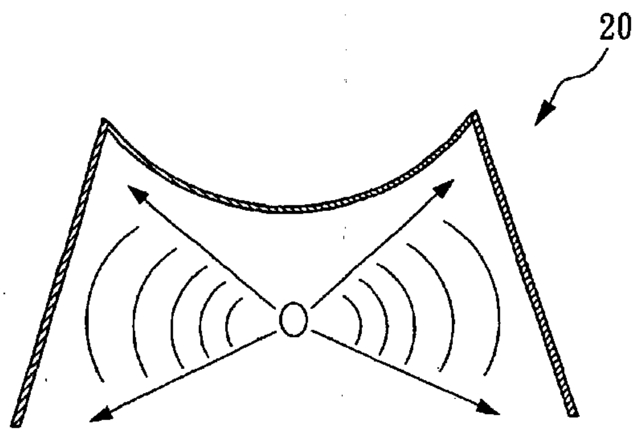


FIG. 3

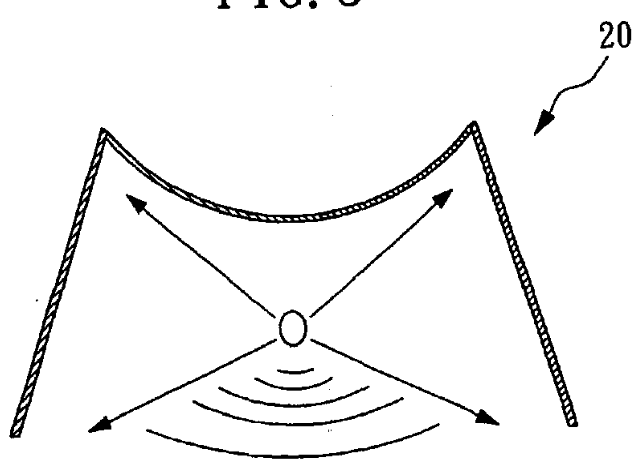


FIG. 4

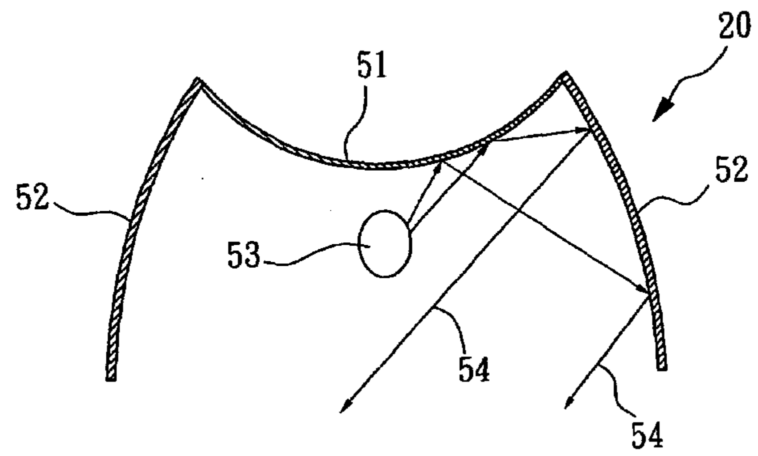


FIG. 5

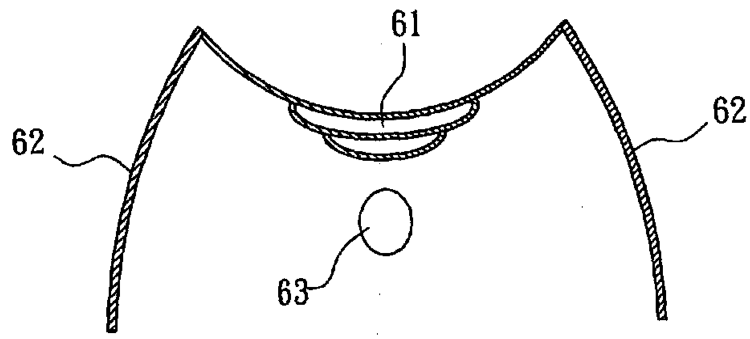


FIG. 6

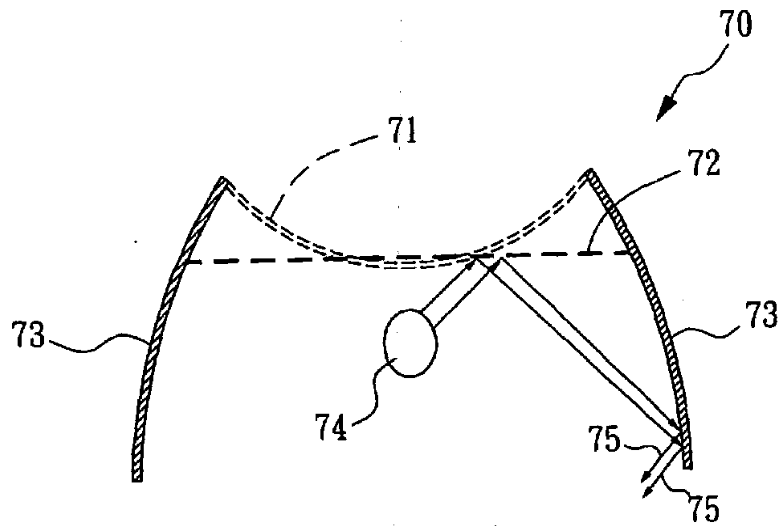


FIG. 7

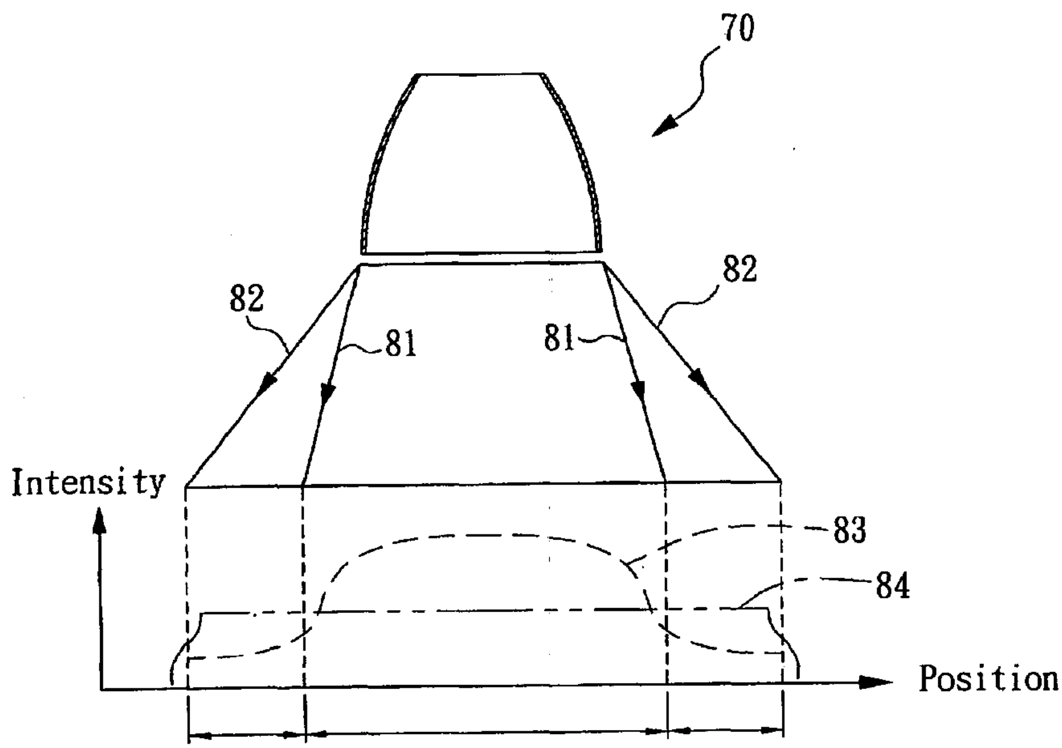


FIG. 8

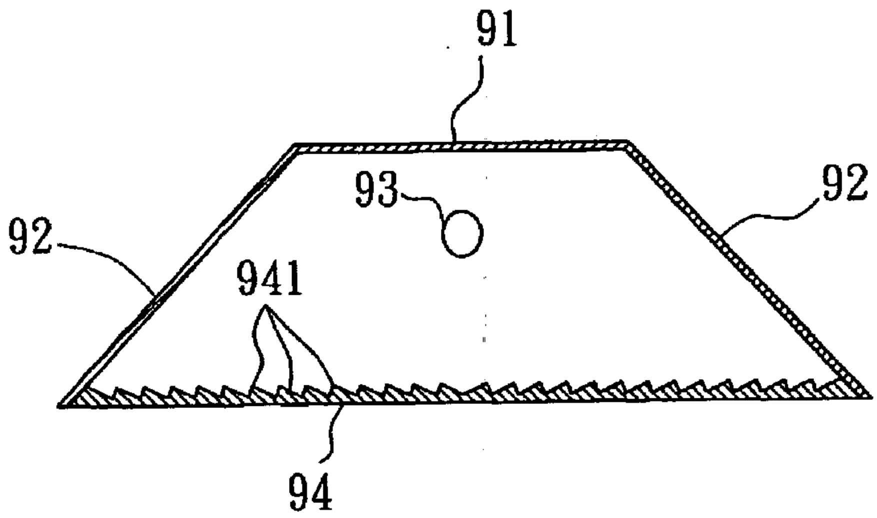


FIG. 9

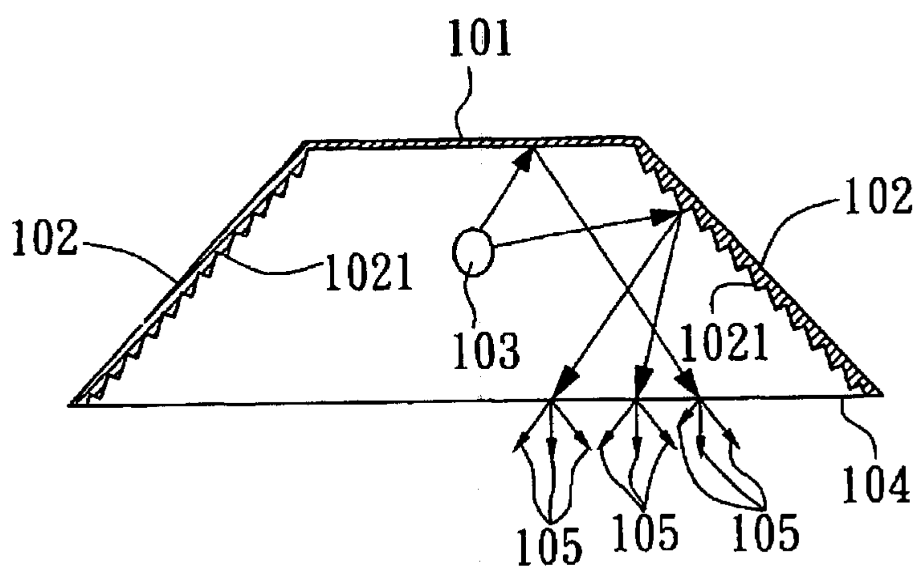


FIG. 10

40. The '526 patent is valid and enforceable.

41. All requirements under 35 U.S.C. § 287 have been satisfied with respect to the '526 patent.

42. Samsung has been and is infringing the '526 patent by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '526 patent, including but not limited to Samsung video projectors.

43. Samsung has been and is continuing to induce infringement of the '526 patent under 35 U.S.C. § 271(b) and contributes to the infringement of the '526 patent under 35 U.S.C. § 271(c), in conjunction with such acts of making, using, offering for sale, and/or importing in or into the United States, without authority, products that fall within the scope of one or more claims of the '526 patent. The infringing instrumentalities have no substantial non-infringing uses.

44. As a direct and proximate result of Samsung's acts of patent infringement, ITRI has been and continues to be injured and has sustained and will continue to sustain substantial damages.

45. Unless Samsung is enjoined by this Court from continuing their infringement of the '526 patent, ITRI will suffer additional irreparable harm and impairment of the value of its patent rights.

46. ITRI has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and ITRI is entitled to recover its reasonable and necessary attorneys' fees, costs, and expenses.

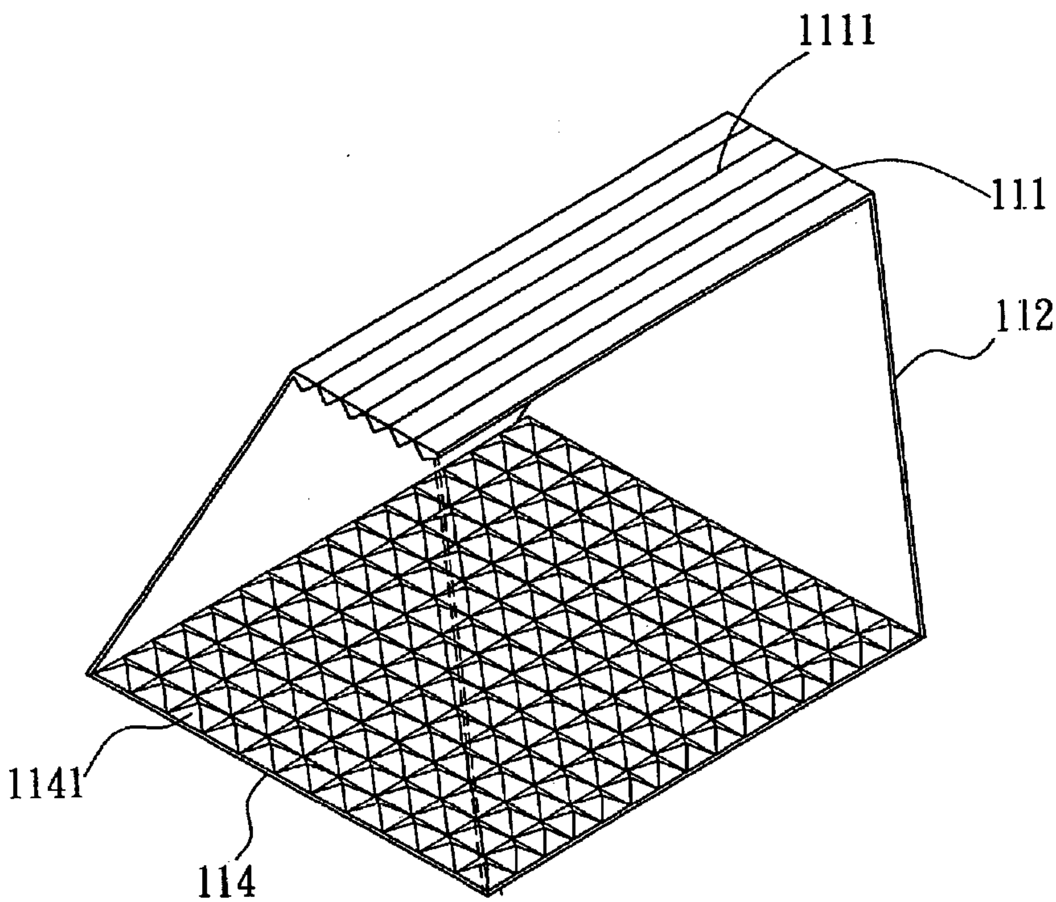


FIG. 11

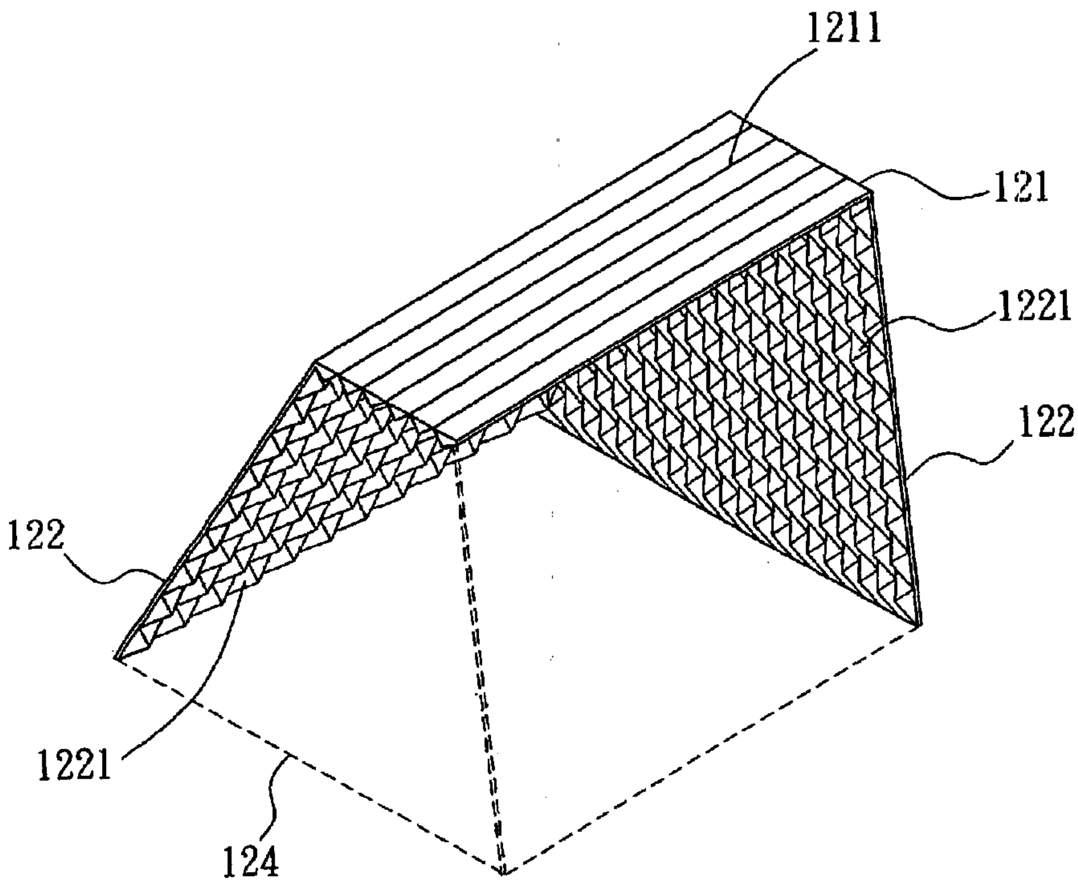


FIG. 12

REFLECTOR WITH NEGATIVE FOCAL LENGTH

FIELD OF THE INVENTION

The present invention relates to a reflector with negative focal length, and more particularly, to a reflector with negative focal length adapted for replacing the reflector with positive focal length arranged at the upper area of a common luminaire screen, by which rays emitting from the lamp of the luminaire are reflected and directed to a preferred discharging area so as to enable the rays to be discharge out of the luminaire by large angles for reducing glare, in addition, the height of the luminaire can be reduced.

BACKGROUND OF THE INVENTION

Before the invention of the light bulb, illuminating the world after the sun went down was a messy, arduous, hazardous task. It took a bunch of candles or torches to fully light up a good-sized room, and oil lamps, while fairly effective, tended to leave a residue of soot on anything in their general vicinity. With the invention of light bulb along and as the science of electricity really got going in the mid 1800s, the easy-to-use lighting technology was such an improvement over the old ways that the world never looked back.

Currently, the application of illuminating device can be categorized into two fields. One of which is the construction industry, that includes all sorts of lighting systems adapted for private housing units, commercial buildings, and public transportation systems like highway and railway, and so on, so as to achieve objects of comfort, beautification, and safety; another filed is the commercial goods, that includes all sorts of light source adapted for auto lamps, indoor lightings and consumer electronics, etc. As in the Year 2000, the largest demand for illuminating devices lays in the United State of American. Generally, the demand for illuminating devices is growing in a rapid path following the growth of global economy. Nevertheless, as the environmental awareness also grows with the global economy, it is in great demand to have green lighting systems for enhancing environmental protection and energy conservation.

Please refer to FIG. 1, which is a cross-section of a lighting system disclosed in U.S. Pat. No. 6,234,645, entitled "LED LIGHTING SYSTEM FOR PRODUCING WHIT LIGHT". As seen in FIG. 1, the white lighting system **1** has at least three light-emitting diodes (LEDs) **11** for providing visible light at pre-selected wavelengths. In operation, the white lighting system **1** is provided with at least one fourth light-emitting diode **12** which, emits visible light in a further wavelength region, the maximum of the spectral emission of the fourth light-emitting diode **12** lying in the further wavelength region from 575 to 605 nm. Moreover, the screen **13** is provided on a side facing the LEDs **11**, **12** with reflection means **14** which diffusely reflect white light so as to effectively blend the light of the LEDs **11**, **12**. However, the luminaire structure as disclosed in the U.S. Pat. No. 6,234,645 has low luminaire efficacy since it can not guide and scatter the rays emitted from the light source such that the referring lighting system **1** can not control the distribution of luminous intensity, not to mention the enhancement of luminance efficacy of a source of light while glare still can not be avoid.

In view of the abovementioned shortcomings, it is require to have an improved illuminating device with high luminaire efficacy for the sake of environmental conservation and also capable of reducing glare.

SUMMARY OF THE INVENTION

It is the primary object of the invention to provide a reflector with negative focal length adapted for replacing the reflector with positive focal length arranged at the upper area of a common luminaire screen, by which rays emitting from the lamp of the luminaire are reflected and directed to a preferred discharging area so as to enable the rays to be discharge out of the luminaire by large angles for reducing glare, in addition, the height of the luminaire can be reduced.

It is another object of the invention to provide a luminaire screen with microstructures arranged thereon for light blending, by which LEDs can be employed as the light sources of a luminaire while the luminaire can have good luminous efficacy.

Yet, another object of the invention is to provide a plate having a plurality of microstructures disposed thereon, which is arranged at the lower portion of a luminaire under the light source thereof so as to better diffuse the rays discharging out of the luminaire and thus reducing glare.

To achieve the above objects, the present invention provides a luminaire with reflector of negative focal length which comprises a light source and a luminaire screen having a reflector of negative focal length, a side screen and a plate; wherein the rays emitting from the light source is divided by three area: a upward incident area including the rays incident to the reflector of negative focal length as seen in FIG. 2; a sideward incident area including rays incident to the side screen as seen in FIG. 3; and a downward incident area including rays incident to the plate as seen in FIG. 4; and the reflector of negative focal length is capable of reflecting the rays of upward incident area; and the side screen is capable of reflecting the ray of the sideward incident area and the reflected rays of the reflector; and the plate being disposed at the lower portion of the luminaire screen beneath the light source has a plurality of microstructures arranged thereon and is capable of accepting the rays of the downward incident area along with both the reflected rays of the reflector and the side screen so as to diffuse the same for discharging.

These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-section of a lighting system disclosed in U.S. Pat. No. 6,234,645.

FIG. **2** is a schematic illustration showing a upward incident area of rays emitting from a light source of the present invention.

FIG. **3** is a schematic illustration showing a sideward incident area of rays emitting from a light source of the present invention.

FIG. **4** is a schematic illustration showing a downward incident area of rays emitting from a light source of the present invention.

FIG. **5** shows a luminaire with reflector of negative focal length according to a first embodiment of the invention.

FIG. 6 shows a luminaire with reflector of negative focal length according to a second embodiment of the invention.

FIG. 7 shows a luminaire with reflector of negative focal length according to a third embodiment of the invention.

FIG. 8 is a profile of light intensity generated by a luminaire with reflector of negative focal length of the invention for glare reduction.

FIG. 9 is a cross-section of a plate being disposed at the lower portion of the luminaire screen beneath the light source according to the present invention.

FIG. 10 is a cross-section showing a plurality of microstructures being arranged on the side screen of a luminaire with reflector of negative focal length according to the present invention.

FIG. 11 is a 3D diagram showing a plate with microstructures disposed thereon according to the present invention.

FIG. 12 is a 3D diagram showing the side screen with microstructures arranged thereon according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

For your esteemed members of reviewing committee to further understand and recognize the fulfilled functions and structural characteristics of the invention, several preferable embodiments cooperating with detailed description are presented as the follows.

The present invention improves structure of the screen of a common luminaire and the surface finishing thereof such that the transmission direction of the rays emitting by the luminaire can be changed. Further, the manufacturing cost of the improved luminaire is not aversely affected, but can provide better illumination for exterior lighting, wide-angle lighting and preferred anti-glare function with reduction of the height of the luminaire.

Please refer to FIG. 5, which shows a luminaire with reflector of negative focal length according to a first embodiment of the invention. In FIG. 5, the top of the luminaire screen 20 is a reflector of single negative focal length 51, such that the cross section of the luminaire screen 20 is a concavity with a side screen 52 connecting to the edge of the reflector 51. By the luminaire screen 20 of FIG. 5, the upward-incident rays emitting from a light source 53 are first reflected to the side screen 52 by the reflector 51, and then are further reflected such that a plurality of discharging rays 54 are generated. It is noted that the discharging rays 54 are discharge out of the luminaire by large angles for reducing glare. In addition, the height of the luminaire can be reduced. However, the luminaire with reflector of single negative focal length can be further improved.

In FIG. 6, which is a luminaire with reflector of negative focal length according to a second embodiment of the invention, the top of the luminaire screen is a reflector of multiple negative focal lengths 61. As seen in FIG. 6, the reflector 61 is a combination of a plurality of concentric concavities shrinking downwardly in diameter and the cross section thereof shows that a side screen 62 is connected to the edge of the reflector 61. By the reflector of multiple negative focal lengths 61, the upward-incident rays emitting from a light source 63 are reflected to the side screen 62 in a diverse manner. However, the manufacture of the luminaire of FIG. 6 is costly and complicated such that it is not feasible in reality.

For the third embodiment of the invention shown in FIG. 7, the reflector with negative focal length 71 similar to that shown is FIG. 2 is replaced by a planar reflector 72 while a

side screen 73 is attached to the edge of the planar reflector 72 similar to that of FIG. 2. By using the luminaire screen of FIG. 7, the space occupied by the luminaire can be reduced since the volume of the luminaire screen is reduced.

For enabling the planar reflector 72 to have the same function as the reflector with negative focal length 71, a Fresnel lens must be formed on the surface of the planar reflector 72 that is composed of a plurality of microstructures forming a regular formation like sawtooth or an irregular formation. Therefore, by the Fresnel lens formed on the planar reflector 72, the upward-incident rays emitting from a light source 73 are reflected to the side screen 73 by the reflector 72, and then are further reflected so as to generate a plurality of discharging rays 75 similar to those shown in FIG. 5.

Please refer to FIG. 8, which a profile of light intensity generated by a luminaire with reflector of negative focal length of the invention for glare reduction. As seen in FIG. 8, the outlook of the luminaire screen 70 with planar reflector is simple and compact, and the discharging angle of a luminaire with planar reflector defined by the two arrows 82 is larger than that of a luminaire without planar reflector, which is defined by the two arrows 81. The luminaire with small discharging angle is pone to generate glare that causes eye-fatigue since the light intensity of the illuminating area of the luminaire directly under the luminaire screen is far larger than that of the off-center area of the luminaire screen. By virtue of this, the use of the planar reflector is intended to enable the light intensity of the illuminating area of the luminaire directly under the luminaire screen to be almost equal to that of the off-center area of the luminaire screen and is reduce to the range acceptable by human eye as illustrated by the profile of light intensity 84 seen in FIG. 8 such that the phenomenon of eye-fatigue can be avoid after working for long hours under the illumination of the luminaire with planar reflector.

FIG. 9 shows a cross-section of a plate 94 being disposed at the lower portion of the luminaire screen beneath the light source 93, the luminaire screen comprising a planar reflector 91 a side screen 92. As seen in FIG. 9, a plurality of microstructures 941 are disposed on the plate whose formation can be of the shape of sawtooth, or each can be a diffuse point of a shape selected from the group consisting of diamond, sphere, column, and irregular shapes. Moreover, the plural microstructures disposed on the plate are formed by a manner selected from the group consisting of apart from one another by an equal interval and apart from one another by different intervals, so as to regulate the amount of rays discharging from the plate 94.

FIG. 10 shows a cross-section of a plurality of microstructures 1021 being arranged on the side screen 102 of a luminaire with planar reflector 101 according to the present invention, the luminaire further comprising a light source 103 and a plate 104. As seen in FIG. 10, a plurality of microstructures 1021 are disposed on the side screen 102 that each can be a diffuse point of a shape selected from the group consisting of diamond, sphere, column, and irregular shapes. Moreover, the plural microstructures 1021 disposed on the side screen 102 are formed by a manner selected from the group consisting of apart from one another by an equal interval and apart from one another by different intervals, so as to enable the discharging of evenly distributed discharging light 105 for preventing glare as well as reducing the volume of the luminaire.

Please refer to FIG. 11, which is a 3D diagram showing a plate 114 with microstructures 1141 disposed thereon according to the present invention, the plate 114 being

arranged at the lower portion of a luminaire screen consisting of a planar reflector **111** and a side screen and being beneath a light source. As seen in FIG. **11**, the plate **114** has a plurality of sawtooth-like microstructures disposed thereon and the planar reflector **111** has a plurality of bar-like microstructures **1111** disposed thereon.

Please refer to FIG. **12**, which is a 3D diagram showing a luminaire screen with side screen **122** having a plurality of microstructures **1221** arranged thereon according to the present invention, the luminaire screen further comprising a planar reflector **121** and a plate **124**. As seen in FIG. **12**, the side screen **122** has a plurality of sawtooth-like microstructures **1221** disposed thereon and the planar reflector **121** has a plurality of bar-like microstructures **1211** disposed thereon.

To sum up, the present invention provides a luminaire with reflector of negative focal length which comprises a light source and a luminaire screen having a reflector of negative focal length, a side screen and a plate. Wherein the rays emitting from the light source is divided by three area: a upward incident area including the rays incident to the reflector of negative focal length; a sideward incident area including rays incident to the side screen; and a downward incident area including rays incident to the plate; and the light source is a lighting means selected from the group consisting of a means of single light source, a means of multiple light sources. The reflector of negative focal length is capable of reflecting the rays of upward incident area which can be a planar lens of negative focal length and is selected from the group consisting of a reflector of multiple focal points and a reflector of signal focal point. The side screen is capable of reflecting the ray of the sideward incident area and the reflected rays of the reflector which has a plurality of microstructures arranged on the surface thereof, wherein each microstructures can be a diffuse point of a shape selected from the group consisting of diamond, sphere, column, and irregular shapes and is disposed by a manner selected from the group consisting of apart from one another by an equal interval and apart from one another by different intervals so as to regulate the amount of rays discharging from the side screen. The plate being disposed at the lower portion of the luminaire screen beneath the light source has optionally a plurality of microstructures arranged thereon and is capable of accepting the rays of the downward incident area along with both the reflected rays of the reflector and the side screen so as to diffuse the same for discharging, wherein each microstructures can be a diffuse point of a shape selected from the group consisting of diamond, sphere, column, and irregular shapes and is disposed by a manner selected from the group consisting of apart from one another by an equal interval and apart from one another by different intervals so as to regulate the amount of rays discharging from the plate. Moreover, in a preferred embodiment, a metal reflective surface with reflective index ranged between 0 and 1 is further attached onto the surfaces of both the reflector and the side screen and the plate is made of a material selected from the group consisting of Polycarbonate (PC), Polymethylmethacrylate (PMMA), and Polyethylene Terephthalate (PET).

In a preferred embodiment, the reflector of negative focal length of a luminaire screen, which can be a planar reflector, is used for reflecting the rays of the upward incident area and thus to increase the times of the same to be reflected inside the luminaire screen, and eventually, for enabling the luminaire to have larger discharging angle and better distribution of luminance. In addition, the disposition of a plate at the lower portion of the luminaire screen beneath the light source enables the luminaire to have more evenly distributed discharging light so that the phenomenon of glare can be reduced and the luminaire is ensured to have the light intensity profile as shown in FIG. **8** while the height of the luminaire can be reduced.

While the preferred embodiment of the invention has been set forth for the purpose of disclosure, modifications of the disclosed embodiment of the invention as well as other embodiments thereof may occur to those skilled in the art. Accordingly, the appended claims are intended to cover all embodiments which do not depart from the spirit and scope of the invention.

What is claimed is:

1. A luminaire with reflector of negative focal length, comprising: a light source and a luminaire screen having a reflector of negative focal length, and a side screen, wherein the reflector of negative focal length is capable of reflecting the upward-incident rays emitting from the light source, and the side screen is capable of accepting the sideward-incident rays emitting from the light source and the reflected rays of the reflector for reflecting the same, wherein the luminaire is configured to evenly emit light directly from the side screen.

2. The luminaire of claim **1**, wherein the overall shape of the luminaire is selected from the group consisting of a symmetric shape and an asymmetric shape with respect to the characteristics of the light source, and a metal reflective surface with reflective index ranged between 0 and 1 is attached onto the surfaces of both the reflector and the side screen.

3. The luminaire of claim **1**, wherein the reflector of negative focal length is made of a negative lens selected from a group consisting of a symmetric lens and an asymmetric lens.

4. The luminaire of claim **1**, wherein the reflector of negative focal length is selected from the group consisting of a reflector of multiple focal points and a reflector of single focal point.

5. The luminaire of claim **1**, wherein the side screen further comprises a plurality of microstructures arranged on the surface thereof, each microstructure being a diffuse point of a shape selected from the group consisting of diamond, sphere, column, and irregular shapes.

6. The luminaire of claim **1**, wherein the light source is a lighting means selected from the group consisting of a means of single light source, a means of multiple light sources; and the light source is selected from the group consisting of point light sources and bar light sources, the point light source being selected from the group consisting of high intensity discharge (HID) lamps and light emitting diodes (LED) the bar light source being selected from the group consisting of cold cathode fluorescent lamps (CCFL) and fluorescent lamps.

7. The luminaire of claim **1**, wherein the reflector is a curved reflector.

8. The luminaire of claim **1**, further comprising a plate with a plurality of microstructures disposed thereon, being disposed at the lower portion of the luminaire screen beneath the light source, capable of accepting the downward-incident rays emitting from the light source along with both the reflected rays of the reflector and the side screen so as to diffuse the same for discharging.

9. The luminaire of claim **8**, wherein the microstructures on the surface of the side screen are disposed by a manner selected from the group consisting of apart from one another by an equal interval and apart from one another by different intervals, so as to regulate the amount of rays discharging from the side screen.

10. The luminaire of claim 8, wherein the plural microstructures disposed on the surface of the plate are formed by a manner selected from the group consisting of integrally formed with the plate and doped the plate with micro particles.

11. The luminaire of claim 8, wherein the plural microstructures are disposed on the plate at a position selected from the group consisting of the top surface of the plate, the bottom surface of the plate, and both.

12. The luminaire of claim 8, wherein the plate is made of a material selected from the group consisting of Polycarbonate (PC), Polymethylmethacrylate (PMMA), and Polyethylene Terephthalate (PET).

13. The luminaire of claim 8, wherein each microstructure of the plate is a diffuse point of a shape selected from the group consisting of diamond, sphere, column, and irregular shapes.

14. The luminaire of claim 8, wherein the microstructures on the surface of the plate are disposed by a manner selected from the group consisting of apart from one another by an equal interval and apart from one another by different intervals, so as to regulate the amount of rays discharging from the plate.

15. The luminaire of claim 8, wherein the plate is a Fresnel lens for diffusing the incident rays thereon.

16. The luminaire of claim 8, wherein the reflector is a planar reflector.

* * * * *

EXHIBIT H

US007250719B2

(12) **United States Patent**
Yu et al.

(10) **Patent No.:** **US 7,250,719 B2**
(45) **Date of Patent:** **Jul. 31, 2007**

(54) **ORGANIC LIGHT EMITTING DIODE WITH BRIGHTNESS ENHANCER**

(75) Inventors: **Liang-Bin Yu**, Taipei (TW); **Tien-Shou Shieh**, Taipei (TW); **Hui-Lung Kuo**, Taipei (TW); **Mei-Rurng Tseng**, Hsinchu (TW); **Pin-Sien Yu**, Taipei (TW)

(73) Assignee: **Industrial Technology Research Institute**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 233 days.

(21) Appl. No.: **11/205,408**

(22) Filed: **Aug. 16, 2005**

(65) **Prior Publication Data**

US 2006/0145600 A1 Jul. 6, 2006

(30) **Foreign Application Priority Data**

Dec. 30, 2004 (TW) .... 93141345 A

(51) **Int. Cl.**
H01J 1/62 (2006.01)

(52) **U.S. Cl.** **313/504**; 313/506

(58) **Field of Classification Search** 313/498, 313/504, 506

See application file for complete search history.

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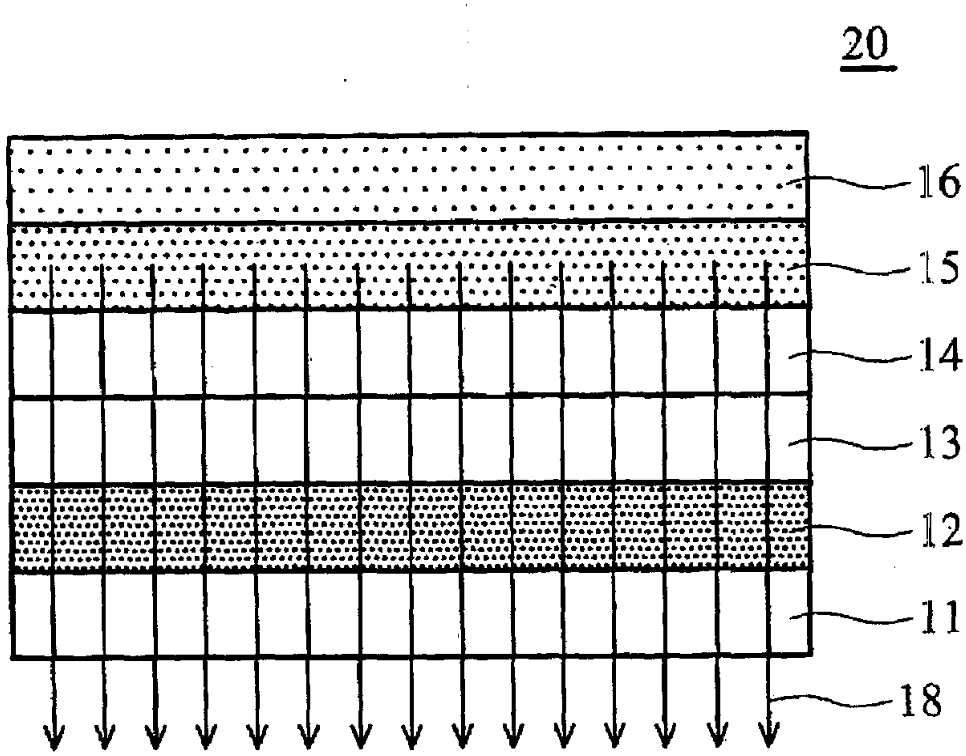
(74) *Attorney, Agent, or Firm*—Quintero Law Office

(57) **ABSTRACT**

An organic light emitting diode (OLED) with a brightness enhancer. The OLED comprises a substrate having a first surface and a second surface oppositely. An anode electrode is disposed on the first surface of the substrate. An organic light emitting layer is disposed on the anode electrode. A cathode electrode is disposed on the organic light emitting layer. A brightness enhancer is disposed on the second surface of the substrate.

23 Claims, 2 Drawing Sheets



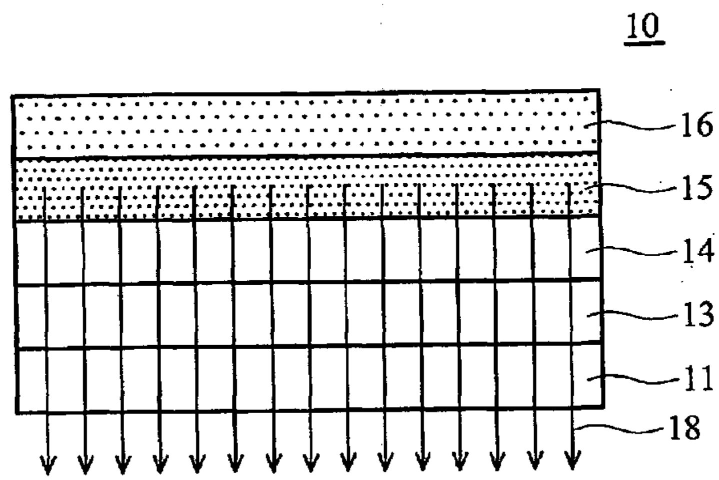


FIG. 1

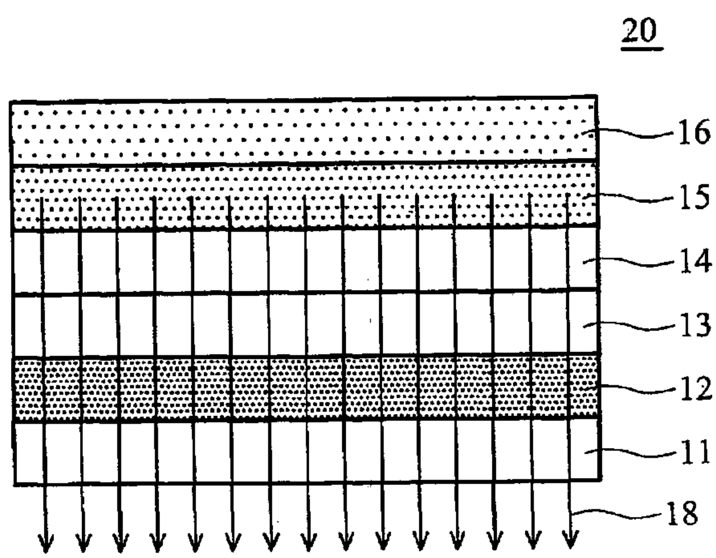


FIG. 2

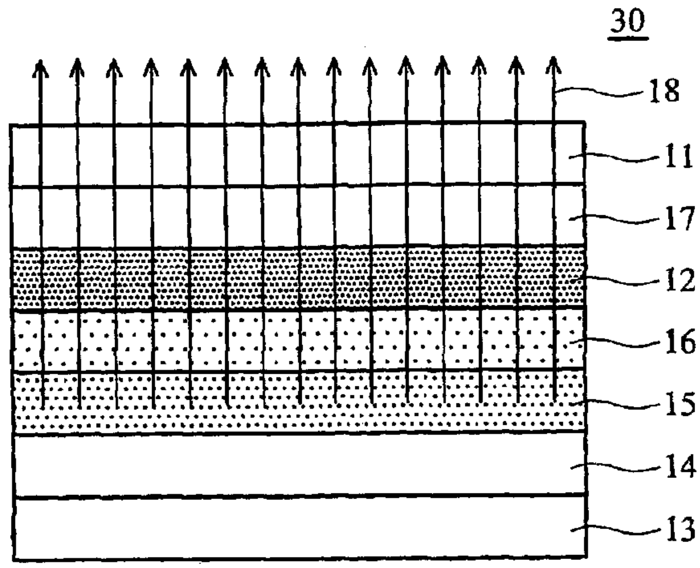


FIG. 3

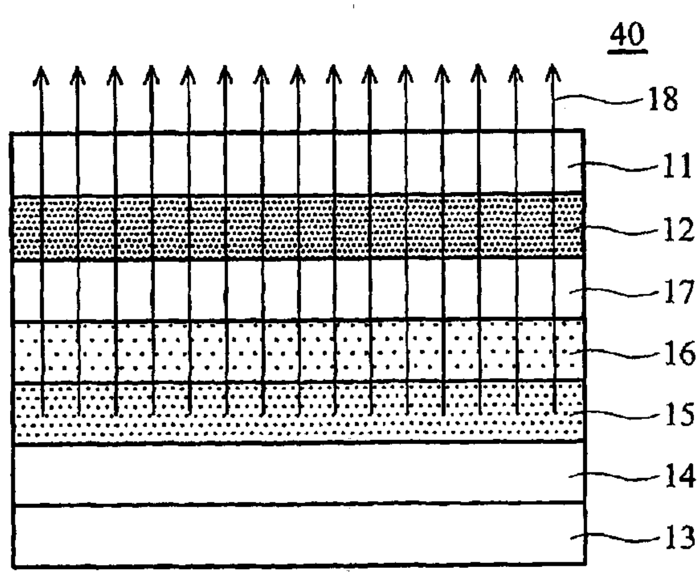


FIG. 4